LANE MEDICAL LIBRARY STANFORD
1770 .W87 1927 OLD
Ventilation and health : the new hygiene
24503196279

NTILATION
ID HEALTH

NEW HYGIENE
F FRESH AIR

THOMAS D. WOOD
ETHEL M. HENDRIKSEN

LANE

MEDICAL LIBRARY

SEAL OF THE LELAND STANFORD JUNIOR UNIVERSITY
SEMPER VIRENS
1885

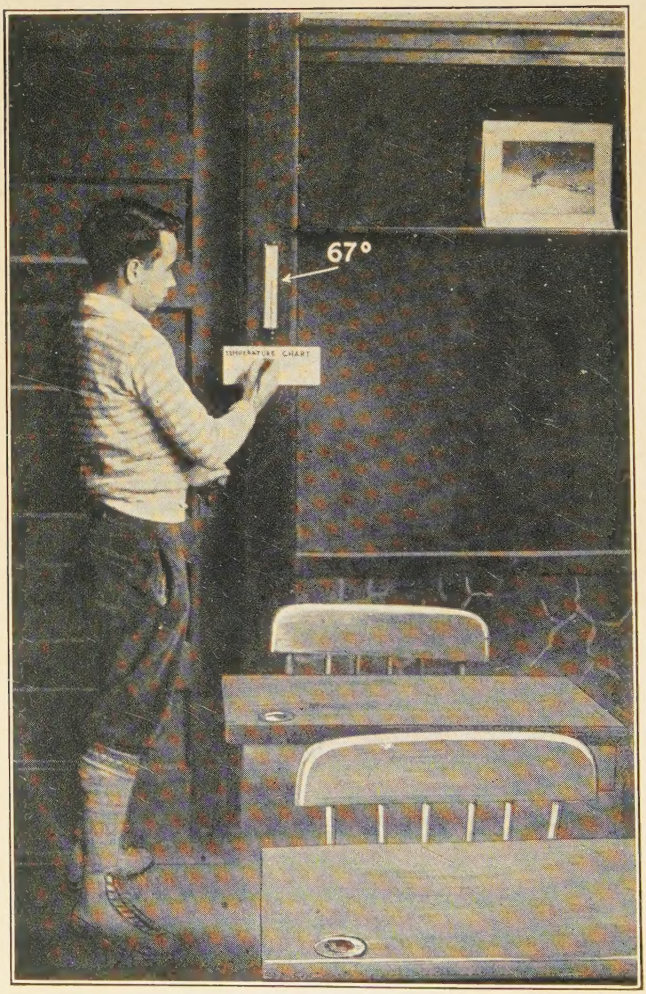
Gift
Dr.C.J.Sullivan

BETTER HEALTH INCORPORATED
MEDICO-DENTAL BLDG. 490 POST STR
SAN FRANCISCO, CAL.

Digitized by the Internet Archive
in 2025

https://archive.org/details/ventilationhealt0000ethe

VENTILATION AND HEALTH



Pupil Assistance in Schoolroom Ventilation at Fairfield, Connecticut.

Room temperature is recorded six times daily.

VENTILATION AND HEALTH

THE NEW HYGIENE OF FRESH AIR

BY

THOMAS D. WOOD, A.M., M.D.

Professor of Physical Education and Adviser in Health Education, Teachers College, Columbia University, New York; Author of "Health and Education," and "The Child in School," and Co-Author of "Byways to Health," etc.

AND

ETHEL M. HENDRIKSEN

Former Executive Secretary, Tuberculosis and Public Health Association of Rochester and Monroe County, New York

D. APPLETON AND COMPANY

NEW YORK LONDON

1927

LANE LIBRARY

COPYRIGHT, 1927, BY
D. APPLETON AND COMPANY

PRINTED IN THE UNITED STATES OF AMERICA

TO THE MEMORY OF

MRS. IRA COUCH WOOD

PIONEER WORKER FOR SCHOOL VENTILATION

PREFACE

Temperature and other air conditions exert important effects upon health and comfort and upon ability to do mental and physical work. Good ventilation is so rare that in cold weather practically all indoor workers suffer from what might be called hot-air disease.

Science has shown us how to control indoor air conditions, but many obstacles intervene to prevent the application of this knowledge. Just as physicians in the time of Pasteur and even later were the greatest obstacles to preventive medicine, so now the ventilating engineers often block progress toward good ventilation. And even as Pasteur, a layman, pointed the way to the present ideals in medical practice, so to-day men outside of the engineering field are chiefly responsible for the advance in the science of ventilation.

It is the physiologist, the public-health worker, and the school-teacher who have discovered what is wrong with indoor air conditions, and it is they who have pointed the way to more scientific and satisfactory practices. The physiologist considers the effect of air conditions on the health, efficiency, and comfort of human beings, while the engineer gives his attention to temperature, humidity, velocity, and volume of the air, largely disregarding the effect upon human beings.

Continuous scientific research work is a need in the

96641

ventilation field to-day. So far as is known, no university or medical school in this country conducts research work in ventilation, although work of this nature has been undertaken by the United States Bureau of Mines, devoted almost wholly to industry. In England the National Institute of Medical Research carries on continuous research in ventilation; the Industrial Fatigue Research Board also conducts experiments in air conditioning in various types of industry.

It is particularly important that some plan of research should be conducted with reference to the various ventilation devices which are offered for school use. Manufacturers at the present time need only to lay out their selling campaigns in order to foist any kind of device, no matter how costly or how inefficient, upon school boards. This is the case in regard to other devices, also, besides "hot-air" machines. With true American extravagance, the more costly the device, the more attention it receives. When the high cost of education is challenged in this country, attention may well be directed to the millions of dollars wasted in mechanical ventilation equipment.

The most scientific study that has been made of schoolroom ventilation may be credited to the Milbank Memorial Fund in the work of the New York State Commission on Ventilation. The outstanding result of this study was to pronounce *modified window ventilation* the most satisfactory for schoolroom use. This simple and economical form of ventilation has since been endorsed by the Joint Committee on Health Prob-

lems in Education of the National Education Association and the American Medical Association and has been recommended for schoolroom use.

In describing modified window ventilation and its use in various types of buildings, it is not intended to discredit mechanical ventilation except in so far as mechanical systems are based upon unscientific principles. Fans will be found necessary in many instances in connection with, or as an aid to, window ventilation, but the cumbersome equipment which has been a part of heating systems is undoubtedly passing out of use.

This book is planned to be of use to all persons who are responsible for indoor air conditions in any type of building. There is ample evidence to prove that modified window ventilation can be used successfully in factories, offices, stores, theaters, churches, hospitals, dispensaries, and private dwellings, as well as in schools.

Teachers in training should be given an opportunity to become acquainted with the most scientific practices in ventilation. It is hoped that this text will prove of value to normal schools and colleges as a supplementary reference.

Community programs for fresh air and ventilation are suggested in this book. Such educational work can be properly initiated in a community by tuberculosis and health agencies, chambers of commerce, women's clubs, or other civic or welfare groups. Public education in fresh air and ventilation is an outstanding need of the day.

While adhering closely to scientific facts and conclusions, these are presented in the language of the layman. It is recognized that much of the information in regard to fresh air and good ventilation has failed to reach those who would be interested to have these facts because of the technical language in which these studies have been recorded.

Acknowledgment is made to Dr. Leonard Hill, physiologist, National Institute of Medical Research, London, England; to Dr. H. M. Vernon, Director of Ventilation Research, National Industrial Fatigue Research Board, London, England; to Professor C.-E. A. Winslow, Chairman of the New York State Commission on Ventilation; to Dr. Frederic S. Lee, physiologist, College of Physicians and Surgeons, Columbia University; to William E. Watt, pioneer in the field of modified window ventilation; to Dr. George T. Palmer, Director of Research, American Child Health Association; to Dr. William Alfred Sawyer, chief of the Medical Department, Eastman Kodak Company, Rochester, New York, who has helped to popularize window ventilation for factories; to John Rankin McLure, whose original work in the field of present ventilation practices in school buildings has awakened great interest in school ventilation; and to others who have assisted in making this presentation possible.

T. D. W.
E. M. H.

CONTENTS

PAGE

PREFACE vii

CHAPTER I

FRESH AIR DEFINED 1

Moderate Temperature Best; Moderate Moisture Required; Variability Important; Air in Motion Essential; Fresh Air versus Clean Air; Summary

CHAPTER II

FRESH AIR ESSENTIAL TO HEALTH 10

Induces Physical and Mental Vigor; Body Needs Cool Air; Even Slight Overheating Harms Health; "Wind Tunnel" for Experiments; Hot Air Wastes Energy; Colds Caused by Lack of Fresh Air; Schools Slow to Profit by Experiments; Many Health Defects Caused or Aggravated by Bad Air; Effect of Bad Air upon Mental Work; More Children Ill in Poorly Ventilated Homes; Absence of Fresh Air an Industrial Hazard; High Indoor versus High Outdoor Temperature; Fresh Air the Last Life-Essential to Receive Attention; Summary

CHAPTER III

WHAT VENTILATION MEANS 33

One Hundred and Fifty Years on the Wrong Trail; Worst Air Found in Lungs; "Crowd Poison" Theory Goes the Way of CO_2 Theory;

PAGE

Effects of Heat and Humidity; Diseases Are Not "Air-Borne"; Problem Is Physical and Not Chemical; Air We Live in More Important Than Air We Breathe; Importance of the Surrounding Air to Body; Open Windows Best for Fresh Air; Health Committee Takes Action; Endorse Window-Gravity Ventilation; Summary

CHAPTER IV

VENTILATION PRACTICES 54

"Standard" Ventilation Violates Scientific Principles; Mechanical Systems Contrasted; Recirculation of Air Economical; Ozone Used to Destroy Odors; Fresh Air by Mechanical Means; Window-Window Ventilation Presents Difficulties; Modified Window Ventilation the Best Practice; Survey of Ventilation in 879 Schoolrooms; Summary

CHAPTER V

VENTILATION LAWS 66

Outworn Theories Form Basis for Ventilation Laws; Twenty-Four States Legislate Against Fresh Air; Present Standard Meaningless; Inconsistencies in Laws; Conspire to Defeat "Upward" Ventilation; Cities in Grip of "Obsolete Standard"; "Code" Deals in Nonessentials; Law Does Not Mention Windows; Factory Laws Ineffective; New York's Subway Requires Open Windows; Cities and States Have Ventilation Codes; Summary

CHAPTER VI

WINDOW-GRAVITY VENTILATION IN SCHOOLS. . . 83

Open-Air Schools Point the Way; A School Principal Opens Windows; Cool Air as Beneficial as Cold Air; School Has Scientific Ventilation; "Smell of the Elephant" Absent in Window-Gravity Schools; Samuel H. Wheeler's Important Work; Comparison of Fan and Window Rooms;

PAGE

Two Systems of Window-Gravity Ventilation Contrasted; Architects Design Window-Gravity Ventilation; Ducts and Their Importance; Ventilation of One-Room Schools; Two-Way Duct an Aid; Plants Thrive Where Children Do Not; Aids to Better Ventilation; Teach Ventilation to Pupils; Window-Gravity Ventilation Gains Favor; Temperature Records Tell the Story; Preheating One Difficulty; Summary

CHAPTER VII

WINDOW-GRAVITY VENTILATION IN FACTORIES . . 113

Architectural Difficulties; Saw-Tooth Construction; Heavy Fumes Removed Where Produced; Clothing Manufacturing Plant Benefited; Windowless Rooms Made Pleasant; Results of Window-Gravity Ventilation; When Fans Are Needed; England Studies Factory Ventilation; Principles of Window-Gravity Ventilation Upheld; Suggested Temperature Standards; Industrial Physician and Ventilation; Summary

CHAPTER VIII

WINDOW-GRAVITY VENTILATION PRACTICABLE FOR GENERAL USE 130

New Ventilation in Office Building; Double-Hung Windows Best for Ventilation; Stores Have Problems to Secure Fresh Air; Air More Important Than Plate Glass; Banks Have Ventilation Problems; Theaters Can Be Well Ventilated; Homes Made Attractive by Pleasant Air; Wheeler Gets Quick Action; Ventilation of a Sleeping Room; Summary

CHAPTER IX

VENTILATION COSTS 144

Costs of Ventilation Systems Compared; A Saving of Fuel in Window-Gravity System; Overheating the Greatest Cause of Waste; Mechanical Equipment Largely Idle; Summary

PAGE

CHAPTER X

Devices to Aid Ventilation 152

Types of Windows Compared; How to Open Windows; Window Deflectors and Their Uses; Window Boards, Cotton Screens and Other Wind Breaks; Humidifiers in Wide Variety of Makes; Position of Electric Fan Important; Refrigerated Air Conquers Summer Heat; Summary

CHAPTER XI

Instruments Used in Ventilation 164

Discovery of the Thermometer; Kata-Thermometer Described; Development of the Thermostat; Check Thermostat with Thermometer; Heat-Regulating Device Desirable; Many Makes of Hygrometers; Hot-Wire Anemometer and Its Use; Summary

CHAPTER XII

Educational Methods 177

Fact Gathering; Exhibits and Lectures; Suggestions for Thermometer Exhibits; Models for Exhibits; Suggested Community Studies; Conference Groups; What to Teach in Ventilation; Suggested Graded Study in Ventilation; Ventilation Literature; General Rules in Firing; Watch Weather Reports; Constant Vigilance Necessary; Summary

Glossary 196

Index 199

ILLUSTRATIONS

PAGE

Pupil Assistance in Schoolroom Ventilation at Fairfield, Connecticut . . . . *Frontispiece*

Cross Section of a Room to Show Relative Strata of Best, Good and Bad Air 43

Diagram to Show How "Standard" Mechanical Ventilation Removes the Best Air from a Room 55

Diagram to Show Movement of Air Currents in a Room Ventilated by the Window-Gravity System 57

Diagram to Show How Window-Gravity Ventilation Operates to Remove the Bad Air at the Ceiling Outlet and to Admit Fresh Air at the Breathing Plane 60

Three Methods of Admitting Fresh Air *Facing* 58

Map Showing States with Ventilation Laws Which Make Fresh Air Impossible for Schoolrooms 68

Interior View of Typical Classroom Ventilated by Window-Gravity System 84

PAGE

Exhaust Ducts in Wall Opposite Windows in Sherman School, Fairfield, Connecticut . . . . . *Facing* 88

Windows Set for Late Fall Ventilation in Schoolroom at Evanston, Illinois . . *Facing* 88

Sherman School, Fairfield, Connecticut, Where the Wheeler System of Window-Gravity Ventilation Was First Demonstrated *Facing* 96

Windows Opened for Late Fall Ventilation in Sherman School, Fairfield, Connecticut . . . . . *Facing* 96

Escape for Overheated Air Shown in Ceiling of Library of an Evanston, Illinois, School . . . . . *Facing* 106

Pupils Recording Thermometer Readings in Schoolroom at Evanston, Illinois *Facing* 108

Pupil Adjusts Windows for Schoolroom Ventilation During a Lesson in Fresh Air Conducted by a Pupil . . . . . *Facing* 108

The Two-Way Ventilation Duct Used by Watt in Factory Ventilation . . . . *Facing* 114

Ventilation of an Interior Room Used for X-Ray Work . . . . . *Facing* 116

Window Set Open for Winter Ventilation in Office; Outlet Through Slightly Opened Transom . . . . . *Facing* 122

PAGE

Detailed Vertical Section Through Classroom Window Showing the Deflector and Steam Heating Radiator 154

Elevation of Classroom Window Showing Radiator with Specially Designed Steam Pipe Along the Top; Showing, Also, Window Shades Hung from the Center of Window to Draw Each Way 157

The Temperature Thermometer with the Health Temperature Plainly Indicated at 68 Degrees F. . . . . *Facing* 166

The Kata-Thermometer . . . . *Facing* 166

The Modern Thermostat with a Regulating Time Device 169

How the Thermostat Operates to Open or Close the Furnace Draft 171

Leaflet Used in Ventilation Campaign by Tuberculosis and Public Health Association of Rochester, New York 180, 181

Street-Car Poster Used in Ventilation Campaign by Tuberculosis and Public Health Association of Rochester, New York 182

"The Joy of Fresh Air" . . . . *Facing* 190

VENTILATION AND HEALTH
THE NEW HYGIENE OF FRESH AIR

CHAPTER I

FRESH AIR DEFINED

FRESH air is a term every one uses. To most minds it implies outdoor air. "Let us go out and get some fresh air," or, "open the windows and let in some fresh air," are common expressions. The public is right in assuming that the first quality of air to be fresh is that it be outdoor air. There is a liveness in outdoor air which invigorates and refreshes. Scientists have yet to discover exactly why this is true. It is obvious that the wind, the sun and the moisture have much to do with the freshness of outdoor air. This freshness is quickly destroyed when air is overheated or when it is stored in enclosed spaces.

Leonard Hill of England was the first experimenter to define fresh air. He says that air to be fresh must be cool rather than warm; dry rather than damp; diverse in temperature rather than uniform and monotonous; moving rather than still.

Air sufficient to maintain life may be had almost anywhere; but fresh air is necessary to maintain the body in health.

Moderate Temperature Best

From the harmful effects on the body which have been observed when room temperature exceeds 68 degrees F., it has been determined by reliable scientific experiments that indoor air in winter, to be fresh, must not be warmer than 68 degrees F.

The importance of cool air is recognized in the treatment of such serious diseases as tuberculosis, pneumonia and heart disease, three of the most prominent causes of death. How much better it would be, then, to prevent these same diseases, so far as possible, by living and working in moderate temperature!

While 68 degrees F. has been quite generally accepted as the upper limit for indoor temperature, there is no index for the minimum low temperature. Cold air is not harmful when the body is properly protected. Children in open-air schools, when warmly clothed, thrive in temperatures between 40 and 50 degrees F. Children usually are comfortable in a lower degree of temperature than are adults.

Too much reliance should not be placed upon comfort opinion in the matter of temperature. Just as the appetite for wholesome food may be destroyed

by an overindulgence in sweets and rich dishes, so the heat-regulating mechanism of the body may be disordered by living in overheated rooms and wearing too much clothing. It is possible to train the body to enjoy a room temperature of 68 degrees F. and below, just as it is possible to learn to like vegetables and green salads.

Hill pointed out to one of the authors that "comfort opinions" in regard to room air are unreliable because the human skin is not stimulated by a monotonous air condition. He recommended a study of pulse frequency, as a method of determining whether a room is overheated. The individual should work with the least pulse acceleration in order to economize the heart action.

Moderate Moisture Required

Most persons have observed the chilling effect which follows when the moisture from the body is evaporated too rapidly either by a damp wind outdoors or by a drying heat indoors. On the other hand the atmosphere of the old-fashioned kitchen where the kettle is steaming on the stove is pleasant and agreeable, on a zero day in winter. Moderate moisture is essential to fresh air; but dampness or excessive moisture causes discomfort.

When indoor air is kept cool, the majority of scientists believe that it will contain natural hu-

midity or moisture, so that it will not be necessary to apply it artificially.

Palmer,[1] chief investigator for the New York State Commission on Ventilation, points out that there is a distinction to be observed between "dryness" and "dryingness." "Dryness," he says, "is not objectionable. Dryingness may be, if excessive." He calls attention to the dryingness of air that is forced into a room at high velocity, such as in mechanical ventilation, and then cites this illustration: "It is moving air that dries, as the housewife knows from the drying of clothes hung on the line on a windy day."

Many persons have had the experience of standing near a hot-air register and shivering although the temperature of the air was hot enough to scorch if one stood close enough to it. The comfort of the body depends upon the maintenance of a certain moisture equilibrium. Evaporation of moisture is essential or the body becomes overwarm, but a too rapid evaporation has the effect of suddenly chilling. Palmer suggests that there exists a neutral zone of humidity somewhere around 65 degrees temperature. At low temperature excessive moisture makes air colder. At high temperature excessive moisture

[1] George T. Palmer, Address before Tuberculosis and Public Health Association of Rochester and Monroe County, Rochester, N. Y., April, 1926.

makes air feel hotter. At intermediate temperature, moisture then has a neutral effect.

With the admission of fresh, outdoor air for ventilation purposes, the subject of humidity is not regarded important in ventilation problems by investigators of the New York State Commission on Ventilation.

Variability Important

Diverse, or variable temperature is stimulating and therefore essential to fresh air. Temperature, if allowed to remain equable, becomes monotonous. It should vary from time to time within a range of two or three degrees, as from 66 to 68 degrees F. or from 65 to 68 degrees F. In window-ventilated schoolrooms with automatic heat control in radiators beneath windows, this variability is secured without much attention by the teacher, but mechanically ventilated rooms tend to maintain a uniform temperature, according to Palmer's experience.

Huntington [2] points out significant facts about variability in the outdoor temperature. He says, for example, that the spring fever, experienced during the first warm days of spring, is due to lack of variability. The same lassitude is to be observed in indoor workers when room temperature exceeds

[2] Ellsworth Huntington, *World Power and Evolution* (Yale University Press, 1919), p. 92.

that for fresh air, and thus tends to lack the stimulation which cool, moving air affords.

Death rates, Huntington shows, are influenced by variability in air temperature. He has observed that a year-around average, day and night, temperature of 64 degrees F. appears to be the most favorable temperature, but that a drop from 75 degrees F. to 64 degrees F., is highly stimulating and causes a decline of 10 per cent in the death-rate.

One of the best safeguards for health is the frequent change from a warmer to a cooler temperature. One must distinguish, however, between slight and sharp variations in temperature. Too great a change in temperature taxes the heat-regulating system of the body and may be a cause of gastro-intestinal disturbances.

Air in Motion Essential

Variability suggests air movement and this is one of the most important qualities of fresh air. Usually there is a difference between gentle motion and a draft. Palmer distinguishes between a draft and a breeze by calling the one objectionable and having the possibility for harm whereas the other is enjoyable and beneficial. Rosenau shows that moving air does not constitute a draft until it has a velocity of 3.5 feet per second, or 2.3 miles per hour. Palmer points out that temperature and humidity have some-

thing to do with the perception of velocity and that in a low temperature, a continuous flow of air even at 1.5 feet per second, or 1.0 mile per hour, would cause the sensation of a draft.

Air movement can be measured by the anemometer and the kata-thermometer (see Chapter XI).

One important benefit of air movement is its effect upon metabolism, the digestion and assimilation of food and other processes by which energy is made available for the uses of the organism. Some experiments were conducted by Wolpert, and reported by Graham Lusk,[3] which indicated that metabolism was more rapid with a breeze moving about 15 miles an hour at a temperature of 59 to 60 degrees F. than with a temperature of 35 degrees F., in a calm. The influence of temperature in this instance will be noted.

Frederic S. Lee says:

> Air in motion promotes efficiency. Accustom yourself to drafts, and especially to big drafts. A small blast of cold air directed against a small area of warm skin may do harm, but the larger the current the more the harm gives way to benefit. . . . The whole moral of the modern physiological doctrine of fresh air may be expressed tersely in two short words, *Keep cool.*[4]

---

[3] Graham Lusk, *The Science of Nutrition* (W. B. Saunders Co., 1919), p. 146.

[4] Frederic S. Lee, "Fresh Air," *Popular Science Monthly* (April, 1914).

Fresh Air versus Clean Air

When the qualities which produce fresh air are named, "freedom from objectionable dust and odors" is a statement often included. Palmer has something of interest to say about the relation of cleanliness to freshness.

> A distinction is to be noted between fresh air and clean air. Clean air has little dust or bacteria or extraneous gases. But air can be clean and yet not fresh. Air can be fresh and yet not clean. The point to be borne in mind is that freshness in air is far more important to health than cleanliness of air. . . . Our failure to achieve better ventilation long before this has been due to confusion over the definitions of healthful air. We have been trying to secure clean air and chemically pure air. We have spent 90 per cent of our efforts on this. What we really need is fresh air—cool air.

This statement does not minimize the importance of clean air which is undoubtedly a quality which air to be fresh should possess.

Leonard Hill named to one of the authors, three functions performed by fresh outdoor air which are essential to health: (1) "Its cooling power which stimulates body heat production and tone; (2) its drying power, a benefit to skin and lungs and (3) its ultra-violet rays, a benefit to skin and blood."

Summary

Fresh air has five qualities: moderate temperature, gentle motion, moderate humidity, variability, freedom from objectionable dust and odors.

An indoor temperature of 68 degrees F. is the maximum for health.

Temperature habits may be acquired just as food habits may be acquired.

Usually a cool temperature will insure a proper humidity.

Variability in temperature as between 66 and 68 degrees F. is stimulating to the body.

Drafts frequently are harmful but air may be in gentle motion without causing a draft.

Air movement favors health and efficiency.

In seeking clean air and chemically pure air engineers have missed the most important factor in ventilation, which is to provide cool air.

CHAPTER II

FRESH AIR ESSENTIAL TO HEALTH

Induces Physical and Mental Vigor

EVERY one notices the invigorating effect of fresh air on a day when the air is dry and crisp, when the temperature is moderately cool and when a gentle breeze is stirring. Contrast such a day with the depressing effect of a muggy day, with a high temperature, when apparently no air is stirring. Temperature and climate have a profound effect upon health and upon physical and mental activity.

Proper ventilation aims to achieve a condition indoors as nearly as possible resembling a cool summer day. Science has put the control of indoor climate within our grasp.

The overheated air found almost everywhere in winter, indoors in the United States, predisposes to colds; causes catarrh; increases susceptibility to tuberculosis, pneumonia and infections that may cause heart disease.

"Fresh air," said Hill to one of the authors, "has a stimulating effect upon all parts of the body.

Through the stimulation to the skin, fresh air increases the heat production of the body, tones up the muscles, improves the ventilation of the lungs, increases the circulation of the blood, and helps to prevent disorders of the alimentary organs, such as dyspepsia and constipation."

The mucous linings of the nose and throat function normally in fresh air and even the eyes feel the comfort of it.

The National Institute for Medical Research in London, Hill reports, has found proof that more of the ultra-violet rays that give protection against the commonest of preventable diseases are derived from the blue sky or bright clouds than from the direct rays of the sun.

This "sky-shine," we are told, is deprived of its benefits in part when it is filtered through ordinary window glass. It must come directly to us outdoors or through open windows or a glass such as "vitaglass" which is penetrable by the ultra-violet rays.

Body Needs Cool Air

Many persons shut themselves away from the important benefits of fresh air because they believe that opening windows causes a draft. In a later chapter it will be shown that windows may be opened in such a way that drafts do not occur.

Since the subject of drafts occupies so important a part of every discussion about ventilation it is desirable to treat it briefly from the viewpoint of the hygienist and physiologist.

Rosenau [1] points out that it is not the draft that causes the infectious cold although drafts may increase the severity of a cold or be the predisposing cause by which immunity is lowered. "Drafts," he says, "have no appreciable injurious effect upon persons in good physical tone. They are, however, injurious to infants, the aged and to susceptible individuals."

"Drafts," Rosenau continues, "are particularly apt to harm persons accustomed only to still, warm air. 'It is not the engine drivers and the firemen of trains that catch cold, but the passengers in the stuffy carriages.' Coddling renders one susceptible to drafts, partly for the reason that the vasomotor impulses which contract the blood-vessels of the skin are not sent out by the nervous mechanism, and, consequently, undue cooling of the part blown on, and perhaps, of the blood itself, occurs."

Leonard Hill continues this same thought when he says, "The more people shut themselves up to avoid cold, and live sedentary 'hot-house' lives, disordering their economy by overeating and at the

[1] Milton J. Rosenau, *Preventive Medicine and Hygiene* (D. Appleton & Co., 1917), p. 196.

same time reducing the combustion of food through body heat stagnation, the more will they suffer and die from catarrhal complaints." [2]

If such bad hygienic habits as those named would result in some immediate and striking form of ill health it would be comparatively easy to convince people of the necessity to live and work always in fresh air. The slowness and insidiousness of the diseases which are induced by a lack of fresh air make the observance of proper air hygiene seem unimportant.

John Shaw Billings,[3] one of the earlier promoters of air hygiene, said in 1893 that the effects upon health produced by exposures to bad air for a few hours only, cannot be considered seriously since these are rarely perceptible unless the air condition is extremely bad. Doubtless he referred in this to the experiments conducted upon human subjects shut up in confined places. For he then goes on to say, "It requires the observation of the effects on the health and life of a number of men exposed to such air for a series of months or of years to demonstrate the slow but certain production of throat and lung troubles, the loss of energy and vitality, and the shortening of life which are thus produced."

---

[2] Leonard E. Hill, *Sunshine and Open Air* (Edward Arnold & Co., London, 1924), p. 31.

[3] John Shaw Billings, *Heating and Ventilation* (1893), pp. 120-121.

Even Slight Overheating Harms Health

That overheating constitutes the chief ill effect of air upon health is clearly demonstrated by the work of the New York State Commission on Ventilation. Even slight overheating of rooms is harmful. A temperature of 75 degrees F. exerts the following effects: a burden upon the heat regulating system of the body leading to increases in body temperature and heart rate, and a marked decrease in the general vasomotor tone; a slight increase in the rate of respiration; a considerable decrease in the amount of physical work performed and a markedly unfavorable reaction of the mucous membrane of the nose. And this is not the only evidence.

Another point of significance in the testimony against overheated air and its effect upon health was brought out several years ago by Reed,[4] who shows that a moderate increase of temperature will augment the action of drugs whether harmful or not. From this he deduces that if body temperature rises even less than one degree the individual would be less resistant to substances breathed or ingested and to auto-intoxicant products of fatigue or metabolic activity. He illustrates the first of these conditions by the fact that mustard gas is from three to

[4]Carlos I. Reed, "Why is Poor Ventilation Harmful?" *American Journal of Public Health* (September, 1919), p. 668.

four times as destructive at 20 degrees C. as at 10 degrees C.

The overheated air found in most schoolrooms, producing a condition of increased body temperature in the pupils, may be responsible, in part, for the epidemics of communicable disease which usually occur in the winter months.

"Wind Tunnel" for Experiments

It is through experiments made on human subjects under varying atmospheric conditions, perfectly controlled, that most of our knowledge about the effects of air upon health has been obtained, both in this country and abroad.

Leonard Hill, of England, has what he calls a "wind tunnel" in connection with his laboratory at the National Institute for Medical Research. This is 20 feet long, 6 feet wide, 8 feet high. In the floor of the wind tunnel is a revolving platform 8 feet long, on which tests or observations can be made upon a subject while walking or running at required speeds. The air is circulated through the tunnel at required velocity by means of a fan, and can be heated or humidified at will.

This plan of investigation and some of the results obtained from it were described by Hill to one of the authors who visited him in his laboratory at the Institute in Hampstead.

"Cool, moving air," he explained, "adequately cools the body by loss of heat from the skin through convection and radiation; by the evaporation of moisture from the respiratory membrane through breathing and by the expenditure of heat made necessary to warm the air breathed."

Hill pointed out that in cool, moving air the skin is comfortably dry and therefore evaporates but little moisture; while in overwarm surroundings the skin sweats, which is the emergency method of cooling. For every fifteen drops of perspiration evaporated there is a loss of 580 calories of heat from the body. Nature's method of cooling is so effective that many persons will sit in an overwarm atmosphere for several hours without feeling any marked discomfort. But all the time the body is under an unnecessary strain. For, in order to cool the skin to produce this sensation of comparative comfort, there must be an increased flow of blood to the skin which means that the heart must beat much faster than normal. The blood which is thus required to cool the skin should rather be flowing to the brain and muscles. Deprived of their proper blood supply the brain and muscles experience fatigue and consequently there is lessened ability on the part of the body to put forth mental and physical effort after a few hours spent in an overwarm room. It is a great advantage to work in cool air.

Hot Air Wastes Energy

Hill has measured the blood flow through the hand and has found that it increases some five times over the normal when a man becomes hot. Hill explained that the expenditure of nervous energy in overwarm surroundings falls on the sympathetic nervous system which keeps up the body tone; coordinates the work of the glands, blood-vessels and bowels. He believes it is a serious thing to exhaust the strength of this system.

But it is in the field of respiratory disease where Hill [5] has made his most outstanding scientific investigations. He was the first research worker to point out the significant relation of cool air to respiratory disease. He shows that it is upon the flow of arterial (oxygen-rich) blood, lymph and cleansing secretions that the body depends for its defense against the infection of germs of respiratory disease which lodge in the nose and throat.

Workers in the average indoor temperature, around 70 degrees F. or slightly above, engaged in sedentary occupations, evaporate about 200 grams of water a day from the respiratory membrane, while outdoor workers in a temperature around 40 degrees F. evaporate 700 grams of water, three and a half

[5] Leonard E. Hill, *Atmospheric Conditions and Efficiency*. (Longmans, Green & Co., 1923), pp. 443-449.

times as much as indoor workers evaporate. As the indoor temperature increases the amount of moisture evaporation decreases. At 85 degrees F. it would be one-ninth of that evaporated by the outdoor man living in cold air. The amount of heat lost by the respiratory membrane in the evaporation of this moisture and in warming up the air breathed into the lungs would be four times greater in the first case cited and ten times greater in the second. This heat loss is made good by the flow of arterial blood through the membrane and the evaporation of moisture is made good by the outflow of lymph from the blood capillaries which percolates through the membrane. The membrane secretes a fluid which washes and cleanses the surface.

It is thus seen that the breathing of cool air is necessary to keep up the health of the respiratory membrane.

Colds Caused by Lack of Fresh Air

Additional testimony of great importance, relative to the effects of indoor atmosphere upon respiratory disease, is presented in the findings of the New York State Commission on Ventilation.[6] Experiments were conducted with fifty-five hundred elementary-school children in schoolrooms under

[6] *Report of New York State Commission on Ventilation* (E. P. Dutton & Co., 1923), pp. 450–451.

three different atmospheric conditions. Two types of rooms ventilated by windows only, had temperatures of 59 degrees F. and of 66 to 67 degrees F., respectively. The third type of room was mechanically ventilated and had a temperature of 68 to 69 degrees F. The period of study covered eight weeks in the late winter of 1916 and twelve weeks in the fall and winter of 1916 and 1917. The results are most significant. In the open-window rooms there was 18 per cent less absences due to colds and 70 per cent less colds among pupils in attendance than in the mechanically ventilated rooms.

Schools Slow to Profit by Experiments

Children, whose health should be most carefully safeguarded by the state which compels them to enter and attend school, are required to sit in overheated and ill-ventilated schoolrooms where they often suffer serious injury to health.

Statistics of physical and medical examinations of school children in the United States show approximately that of the twenty-four million pupils in the schools 75 per cent or at least eighteen million have health defects. From 20 per cent to 30 per cent, five to seven millions of them, are suffering from some degree of malnutrition. Seventy-five per cent at least in most schools, and often many more than this, have defects of the teeth. From 5 per cent

to 15 per cent of the school children, one million to three millions of them, have had, at some time in their lives, tuberculosis. At least two millions are handicapped by obstructed breathing due to adenoids or enlarged tonsils. From six millions to twelve millions are suffering from diseased and infected tonsils and enlarged cervical glands. Ten to twelve per cent of all the children have defective vision, in schools where the eye defects have not been carefully detected and corrected. Twelve to fourteen per cent have some defect of hearing most of which cannot be corrected. At least three millions to five millions have defective posture or some other form of joint defect. At least a quarter million have organic heart disease. An indeterminate number are predisposed to some form of serious nervous defect.

Many Health Defects Caused or Aggravated by Bad Air

Doubtless overheated and stagnant air resulting from faulty ventilation in schools and homes is an important factor in causing or aggravating many of the serious health defects of children. Malnutrition, a common and serious defect in childhood, is frequently the result of other health defects, such as adenoids, diseased tonsils, defective teeth, overfatigue and loss of appetite; all interrelated causes and all in part traceable to a lack of fresh air and

to poor ventilation. Adenoids and enlarged tonsils are believed by some of the best health authorities to be attributable, in part at least, to lack of fresh air. Tuberculosis, in a significant part of the conditions contributing to it, is prominently an indoor disease. Fresh air is one chief factor relied upon by our best physicians for the prevention and cure of tuberculosis.

The mucous membranes are especially susceptible to damage from overheated and excessively dry air. The eye is no exception to this.

Posey [7] says:

> On account of the proximity of the large air spaces, or sinuses, which communicate with the nose, the cavity of the orbit not infrequently participates in inflammatory conditions of those structures. Pus in a sinus may give rise to abscesses in the orbit, and the inflammatory process attacking the eye may lead to serious disease of that organ.

Bad air tends to weaken the general vigor of the body. The incentive to brace up is lacking to persons when they are in bad air. This has an important relation to physical indolence and poor body posture, often associated with malnutrition.

Damage to the circulatory system leading to heart disease is one of the various evils caused by over-

[7] W. C. Posey, *The Hygiene of the Eye* (J. B. Lippincott Co. 1918), p. 158.

heated air. When the temperature of a room rises even slightly above 68 degrees F., the body becomes feverish, the pulse rate and respiration rise, and the blood-vessels, in time, become weakened.

The importance of the control of indoor air conditions, to permit every child and adult to consistently live in fresh air is an essential health need since so little time is spent outdoors compared with the long hours spent indoors.

Effect of Bad Air upon Mental Work

From the known effects of high temperature on body mechanism it is evident that in time, mental efficiency would be lessened. The New York State Commission on Ventilation in its experiments, however, did not succeed in showing this result. E. L. Thorndike,[8] the psychologist of the Commission, who had charge of the experiments relating to mental efficiency and temperature, states:

> With the forms of work and lengths of period used, we find that when an individual is urged to do his best he does as much, and does it as well, and improves as rapidly, in hot, humid, stale and stagnant air conditions . . . as in an optimum condition. This result was obtained when the individuals were subjected to the bad conditions four hours a day for five

[8] E. L. Thorndike, W. A. McCall and J. C. Chapman, "Ventilation in Relation to Mental Work," *Contributions to Education*, No. 78, 1916.

consecutive days. Enough individuals were tested to make the result entirely reliable.

The hot conditions cause a relative rise in body temperature and quickening of the pulse as well as the various annoying sensory conditions due to the heat and perspiration. These may have an effect when continued week after week that they do not display over a short period.

Dullness, mental inertia, sleepiness and headache used to be attributed unquestionably to the chemical constitution of the air breathed in crowded rooms due to its having been breathed before. This orthodox view of the recent past is now discarded as fantastic; the harm being attributed to the heat and stagnancy of the air as it meets our skins. . . .

"Our experiments need repetition and extension," Thorndike concludes with reference to the effect of bad air on mental work and efficiency.

Burnham [9] reports the experiments of Lehmann and Pederson [10] in Leipzig in tests made upon their subjects' ability to add each morning either directly before or after dynamometric tests; adding seven columns of fifty-one place numbers. Of all external factors, temperature was the one that did have a demonstrable influence. There appeared to be a de-

---

[9] William H. Burnham, "The Optimum Temperature for Mental Work," *Pedagogical Seminary* (1917), Vol. 24, pp. 53–71.

[10] A. Lehmann and R. H. Pederson, *Das Wetter und unsere Arbeit.*

cidedly optimum temperature for the best performance in adding.

These studies made at Leipzig would indicate that the different mental functions are differently affected by the different factors in the weather. Memory performance seems to be dependent upon light, temperature and atmospheric pressure; but, as regards the process of adding Lehmann and Pederson found only a dependence upon the temperature.

Their investigations of the muscular strength in relation to temperature are also significant. They found that there was an optimum temperature for the muscular strength, this optimum varying with the individual. Both higher as well as lower temperatures decrease one's strength. It is especially interesting that the optimum temperature for adding is lower than for muscular strength. But this fact seems established by the work of Lehmann and Pederson.

"The contradiction between the results found by Lehmann and Pederson and those found by the New York State Commission on Ventilation are apparently easily explained," says Burnham. "The Commission found that when the subjects were allowed to work as they pleased their work fell off in the higher temperature and they showed a distinct disinclination to work. But when they were

paid for their work they did well. The children in school had no such impetus."

Observations of the effect of temperature upon mental work were made in three classrooms in Crawfordsville, Indiana. At a temperature of 80 degrees F. the class was restless, dull and incapable of continued mental effort; at a temperature of 76 degrees F., the class was dull, sleepy, with penmanship poor; at 75 degrees F. the class was dull and complained of heat; at 74 degrees, not quite so dull; at 72 degrees, restless; at 70 degrees, excellent work, cheerfulness in class; at 68 degrees, best work, today seemed their best; at 66 degrees, splendid work, some complained about the room being cold; 60 degrees, too cold for good work, complained of the cold.[11]

More Children Ill in Poorly Ventilated Homes

The road to ill health often is opened to the child in the home before school attendance begins. Homes are quite as delinquent in their ventilation as are public buildings. Sometimes this is partly due to faulty construction of houses, as in tenements where inside rooms exist or where houses are built too close to each other.

---

[11] L. N. Hines, "The Effect of School Room Temperature on the Work of Pupils," *Psychological Clinic* (1909), Vol. 3, pp. 106-113. Summarized.

The United States Children's Bureau has reported a study made in England in 1910 to show a contrast between good and bad house ventilation. A comparison was made of child health in "through" houses, meaning houses open to the air both front and back; and "back-to-back" houses, meaning houses built close to each other at the back with no space for adequate circulation of air between them. "In the group comprising the children under five years of age, not only were the deaths from diseases of the respiratory tract, such as pneumonia and bronchitis, far more frequent in the badly ventilated houses, as might have been expected, but the deaths from diseases caused by defective development and malnutrition were 40 per cent higher in the poorly ventilated houses than in those which had *through* ventilation, showing the great importance of fresh air to all young children."[12] Social and economic differences also probably had some bearing upon the situation.

Accustomed to poorly ventilated schoolrooms and homes, children grow up and encounter the same conditions in industry and in the business field. Individuals are, generally, unaware that practically every function of the body is weakened by the absence of fresh air.

---

[12] "Care of Children," Series No. 2, Children's Bureau (Publication No. 8, United States Department of Labor, 1914).

"Overfatigue," that great American complaint, is frequently not so much due to insufficient sleep and rest, as it is to a lack of fresh air.

Absence of Fresh Air an Industrial Hazard

Loss of strength was the complaint which led one man to seek a tuberculosis clinic. He was thought to have incipient lung trouble. Upon being questioned he stated that the work, at which he was expert, required him to remain in a closed room, with no fresh air, from 7:30 A.M. until 5:30 P.M. daily. It was decided by the physician who examined him that he was exposed to an industrial hazard.

Although it has not so been considered, operations which require that no outside air shall enter workrooms, as in some industrial operations, should be definitely classed among the industrial hazards. These operations should be performed by workers in shifts of not more than two hours' duration to reduce the hazard as much as possible.

An interesting example of the effect of the opposite conditions on work was that of a candy factory where the health of chocolate dippers who worked at a temperature of 60 degrees F. was very much better than the health of workers in departments where temperatures were higher. It is not recorded, however, that this company took any definite steps

to reduce the temperature in the other departments.

Industry still is wasteful of human life and moves very slowly to safeguard the health of workers.

High Indoor versus High Outdoor Temperature

"If high temperature is so harmful why do we not all die in summer?" some one will ask. "Some of the more sensitive do," replies Winslow[13] and refers to the higher infant mortality rate in hot weather.

There are, however [he continues], three very good reasons why high summer temperatures are not so harmful as much less extreme temperatures maintained indoors in winter. One of these reasons is that the air in summer, either outdoors or indoors with windows open, is almost always in active movement. In a series of observations made outdoors in New England summer weather, I have found that temperatures at least as high as 75 degrees F. are entirely comfortable and show excellent kata-thermometer readings. Similarly, a temperature up to 80 degrees F. may be made satisfactory by the use of an electric fan. The cooling effect of air movement is, of course, enormously influenced by clothing. In the Pittsburgh studies air movement produced astonishing results in rendering high temperatures bearable for men unclothed above the waist.

In the second place, the effects of summer tempera-

[13] C.-E. A. Winslow, *Fresh Air and Ventilation* (E. P. Dutton & Co., 1926), pp. 75, 76, 77.

ture are greatly minimized by the factor of acclimatization. We are all familiar with the lassitude which overcomes us on the first warm days of spring; but, as the season proceeds, the circulatory system gradually adjusts itself so as to cope more and more successfully with high atmospheric temperature. Vernon has studied this problem experimentally and finds that during one month of experimentation the endurable limit of wet-bulb temperature for his subjects was increased from 82.5 degrees to 88.5 degrees F. The subjects not only showed greater power of endurance but the effect of a given temperature upon their pulse rate and respiration was markedly diminished.

Finally and most important of all, the gravest effects, those on susceptibility to respiratory disease, are naturally not produced in summer because they depend upon the shock incident upon exposure to the chill outside air following upon the lowered circulatory tone due to a high indoor temperature.

Fresh Air the Last Life-Essential to Receive Attention

Of the three essentials of life—water, food and air—man has made less progress in the control and use of his air supply than in the control and use of water and food supplies. Poor ventilation and a lack of fresh air are to be found almost universally.

When the hours spent indoors by both adults and school children are considered, it will be realized that in the winter months the average adult

who is a city dweller gets less than two hours out of the twenty-four in the open air, and school children not more than two to four at the most. The majority of our population now suffer more or less from the lack of fresh air. Outdoor air is the most valuable health tonic known; it is the cheapest and the most universally neglected tonic.

A prominent statistician, Roger Babson, himself an example of what the open-air life will do to restore and build up health, says:

> For many years I have had an opportunity to check up personally the sickness experiences of several hundred people in active business—the study being made under the daily supervision of graduate nurses. Almost everybody realizes in a general way that sickness increases in the winter; but systematic observation shows with startling clearness the lost time, the lowered efficiency, the suffering, which accompany the winter months.
>
> Most people tend to live indoors in winter and outdoors in summer. It is not merely the cold weather itself but the indoor life that makes winter a time of sickness and death.[14]

It is a fascinating dream to visualize the maximum health which might be ours if we lived always in the open air and observed other rules of healthful living. Such play of the imagination may help

[14] Roger Babson, *Review of Reviews* (November, 1925), Vol. 72, No. 5, p. 479.

those of influence, in programs of health and welfare, effectively to strengthen their efforts to increase the use of fresh air.

Science has shown us how we may control indoor air conditions. It only remains to convince the individual that fresh air will materially help to promote health, prevent sickness and prolong life.

Summary

Temperature and air movement have a profound effect upon health and upon physical and mental activity.

Moderate drafts have no appreciably harmful effects upon persons in good physical tone.

An overwarm atmosphere increases the expenditure of nervous energy and makes extra work for the heart.

Cool surroundings are of utmost importance to stimulate men to work; to promote body heat production, utilization of food, appetite, vigor of circulation and depth of respiration; and to prevent alimentary disorders.

Fresh air causes a greater flow of arterial blood and lymph and of all the fluids which constitute the body's natural defense against the germs of respiratory disease.

Scientifically controlled investigations found 18 per cent more absences from respiratory diseases and 70 per cent more respiratory illness among children in attendance in mechanically ventilated, closed-window schoolrooms, than among children in attendance in naturally ventilated, open-window schoolrooms. Tempera-

tures between 66 and 68 degrees F. are found to be best for health.

Malnutrition, adenoids and diseased tonsils, enlarged cervical glands, tuberculosis, infections leading to heart disease, and nervous disorders in school children are believed to be traceable, in part, to the lack of fresh air in schoolrooms.

Chocolate dippers working in low temperature were found to have less illness than workers in other departments of a candy factory where the temperatures were higher.

Fresh air, although life's most immediate essential, has not captured the public interest and conviction as have a pure water supply and clean food.

CHAPTER III

WHAT VENTILATION MEANS

THE word ventilate comes from the Latin, *ventilare,* meaning to winnow or to fan; and from the Latin, *ventus,* meaning the wind. Thus one readily conceives the ideas of wind in motion and of fresh air. Ventilation is the process or act of supplying fresh air continuously to occupied, enclosed spaces. "The effect of civilization in causing mankind to remain indoors for long periods has made proper ventilation of great and increasing importance." [1]

One Hundred and Fifty Years on the Wrong Trail

Lavoisier, a French scientist, discovered the component parts of the atmosphere in 1775. This marked the beginning of the scientific study of ventilation. It was Lavoisier who started us on the wrong trail when he concluded that an excess of carbon dioxide (CO_2) rather than a lack of oxygen was the cause of asphyxiation in badly ventilated places. The carbon dioxide theory dominates most mechani-

[1] J. R. Allen and J. H. Walker, *Heating and Ventilating* (McGraw-Hill Book Co., 1922), p. 206.

cal ventilation practice even to-day, although it was discredited in 1863 by Pettenkofer, a German physiologist.

Pettenkofer inadvertently perpetuated the very idea he condemned, however, by announcing a method of measuring the carbon dioxide content of expired air. He said that 0.6 cubic feet per hour per pound weight, was the approximate amount of carbon dioxide in expired breath. So the carbon dioxide limit for good ventilation was fixed at 6 parts, or 2 parts above the normal (4) in 10,000 parts of air. Then, by dividing "the amount of carbonic acid (carbon dioxide) exhaled in an hour, by the limit of respiratory carbonic impurity for good ventilation," the number of cubic feet of fresh air per hour required per person was determined as follows:

$$\frac{0.6}{0.0002} = 3{,}000 \text{ cubic feet}$$ [2]

Pettenkofer's statement, that he believed carbon dioxide to be harmless in amounts likely to occur in connection with ventilation, was wholly disregarded. It is readily apparent that one man's opinion set against one hundred years of belief would hardly prevail. Also one can imagine with what

[2] John S. Billings, "Ventilation and Heating," *Engineering Record* (1893), p. 123.

avidity Pettenkofer's announcement was seized upon, since some measure for carbon dioxide had been sought so long and had baffled scientists so repeatedly.

But subsequent experiments were conducted under the direction of Leonard Hill in England and by John S. Billings and others in this country, and lately by the New York Commission on Ventilation; all confirming Pettenkofer's pronouncement that carbon dioxide, in amounts likely to occur in the most crowded rooms, is harmless to health.

Modern scientists believe carbon dioxide can be wholly disregarded in connection with the problems of ventilation.

Notwithstanding this fact, representative school buildings and other buildings being constructed today are installing mechanical ventilation equipment based on the theory that carbon dioxide is the harmful element in expired air, which must be removed in order to provide good ventilation, according to John R. McLure in his study, *The Ventilation of School Buildings.*

Worst Air Found in Lungs

A comparison of the oxygen and carbon dioxide content of outdoor air, exhaled air, and the poorly ventilated rooms shows that chemically the worst air of all is to be found in the lungs.

COMPARATIVE OXYGEN AND CARBON DIOXIDE CONTENTS

	Oxygen per cent	Carbon Dioxide per cent
Pure air	21	0.04
Air in lungs	16	5.00
Air in worst ventilated rooms	19	0.40
Air which chemically produces physiological injury	14	3.00 [3]

The air in the worst ventilated rooms is never without sufficient oxygen to maintain health; nor is it ever dangerously charged with carbon dioxide. Even in the worst ventilated room the air is chemically much better than that in the lungs.

Scientific experimenters in this country and abroad have used the following experiment to prove that it is temperature and not any chemical condition of the air which causes physical discomfort:

A subject is confined in an atmosphere of high temperature, but is given fresh air to breathe through a tube. Great discomfort is experienced.

The subject is then placed in cool air but is given respired air to breathe through a tube. No discomfort is experienced.

This experiment has been conducted repeatedly

[3] Clair Elsmer Turner, *Personal and Community Health* (The C. V. Mosby Co., St. Louis, 1925), p. 326.

by different groups of investigators and with a suitable number of subjects so that the results are entirely reliable.

"Crowd Poison" Theory Goes the Way of CO_2 Theory

The "crowd poison" theory also has been entirely discredited by competent investigators.

Tragedies such as the "Black Hole of Calcutta" and the steamer *Londonderry,* and other similar although less fatal calamities in history have tended to fix the belief in "crowd poison" in the minds of the public. It is thought by many that expired air contains "morbific matter," "organic effluvia" or other supposedly injurious substances.

The tragedy of the "Black Hole" has been described as follows:

On the capture of Fort William in Calcutta in 1756, by the Nawab of Bengal, the Europeans who remained, surrendered, and were driven at the point of the sword into the guard room, a chamber scarcely 20 feet square, with but two small windows, which were strongly barred with iron. Into this on a sultry night, 146 men were pressed, giving to each an area of less than 18 inches square. Very soon after they were crowded in, an almost incredibly profuse perspiration broke out upon them, which was followed by consuming and increasing thirst. They became furious and loaded the guards with insults to provoke them to fire, in which

they failed. They made furious cries for water; a little of it was brought to them in hats and forced through the bars. The stronger forced their way to the window and bore down and trampled to death the weaker ones. By half-past eleven most of the living were outrageous and quite ungovernable. At six in the morning the order arrived for their release. At that time only 23 were left alive, and so exhausted were the survivors that more than 20 minutes elapsed before they could remove the dead from the door so they could make sufficient opening to pass out one at a time. Most of those who survived were affected with a form of fever resembling typhoid, which was followed by an eruption of large and painful boils.[4]

The calamity which occurred on board the *Londonderry* which left Sligo for Liverpool, December 2, 1848, with two hundred passengers, has been described as follows:

Stormy weather came on, and the captain ordered every one to go below. The cabin for the steerage passengers was only 18 feet long, 11 feet wide and 7 feet high. Into this small place the passengers were crowded; they would have suffered inconvenience, if the hatches had been left open; but the captain ordered these closed, and—for some reason not explained—he ordered a tarpaulin to be thrown over the entrance to the cabin, and fastened down. The wretched passengers were now condemned to breathe over and over again the same air. This soon became intolerable. Then occurred a horrible scene of frenzy and violence,

[4] John S. Billings, *op. cit.*, p. 95.

amid the groans of the expiring and the curses of the more robust; this was stopped only by one of the men contriving to force his way on deck, and to alarm the mate, who was called to a fearful spectacle; seventy-two were already dead, their bodies were convulsed, the blood starting from their eyes, nostrils, and ears.[5]

These deaths in the "Black Hole" and on the steamer *Londonderry* have heretofore been explained as due to breathing "over and over again" the same air. According to present knowledge and belief the cause was oppressive heat.

Jarvis says:

The difference between the faintness and languor of a crowded room and the deaths in the Black Hole is a difference only in degree, but not in kind; and it is only by step after step, in the same course of corrupting atmosphere and depreciating life, that our children in the unventilated schoolrooms . . . might go from the inconvenience they there feel to the death from which they shall wake no more.[6]

A dispatch from Chicago, May 26, 1925 states: "Sixteen pupils collapsed to-day in the Blaine School, due, their instructors said, to entering a warm room after competitive exercises in preparation for field day." [7]

---

[5] George Henry Lewes, *The Physiology of Common Life* (D. Appleton & Co., 1875), Chap. vi.

[6] Edward Jarvis, *Physiology and Laws of Health* (A. S. Barnes & Co., 1866).

[7] News item, *The World,* New York, May 26, 1925.

Effects of Heat and Humidity

A coöperative study of the physiological effects of heat and humidity has been conducted by the Bureau of Mines and the United States Public Health Service coöperating with the American Society of Heating and Ventilating Engineers, in the Research Laboratory of the Bureau of Mines at Pittsburgh, Pennsylvania.

The first phase of the work dealt with the physiological effects of high temperature and high humidity on human subjects at rest in still air. The symptoms experienced by subjects in this study parallel those just reported in actual life:

> The chief symptoms complained of under the adverse conditions of temperature were as follows: The subjects, who frequently, on entering the chamber, were in a happy mood and of a joking disposition, soon became restless and irritable. They complained of headache and palpitation of the heart. The headache soon became throbbing in nature, and the palpitation distressing. Great thirst was experienced. The eyes became inflamed and sore. A feeling as of a weight on the chest was noticed. The voice suffered somewhat, in that it became an effort to speak. Dizziness and confusion followed. After leaving the chamber it was necessary to sit down and rest for five or ten minutes before taking a shower. Weakness and a "dragged out" feeling continued for some time, depending upon the severity of the test. A metallic taste

was a noticeable symptom, and persisted for one or two hours following the high temperature experiments.[8] . . .

Of the physiological disturbances that occur when subjects are exposed to abnormal atmospheric conditions, the results of the experiments emphasize the importance of the circulatory system. Were this work confined to a single physiological measure of discomfort due to high temperature—in the light of present experimental evidence—the pulse rate would be selected as probably the best index.

Without exception, every subject began to complain of unbearable symptoms when the pulse rate materially increased, irrespective of the rise in body temperature. Though no arbitrary rate at which certain symptoms occur has been determined, the consensus of opinion, as expressed by the subjects themselves, indicates that very uncomfortable sensations are felt after the pulse rate exceeds 135 pulsations per minute, and the atmospheric condition becomes unbearable and the subject desires to leave the chamber immediately when the pulse rate exceeds 160 per minute. . . .

The rise in blood pressure no doubt contributes to the discomfort. Subjects describe the sensation felt on reaching the unbearable condition as follows: First, a slight palpitation of the heart occurs, which increases in severity until a feeling of floating in the air is experienced. This is accompanied by dizziness, and fre-

---

[8] W. H. McConnell and R. R. Sayers, *Report of Investigation on Some Effects on Man of High Temperatures* (Bureau of Mines, Department of the Interior, March, 1924), Serial No. 2584.

quently by a numbness or soreness of the face, and by nausea.

The subjects remained in the test chamber for a period of three hours whenever possible. In some experiments, where the temperature was high and accompanied by a high humidity, the subjects were not able to remain therein for the entire period, as collapse and even death might result before the lapse of three hours.[9]

It is in no sense because air is breathed "over and over again" that it is harmful to health, according to these scientific experiments, but entirely because of the high temperature, stagnation, and humidity, or lack of proper humidity.

The scientific experiments of Billings, Mitchell and Bergey in this country have established the harmlessness of organic matter in expired air. Their conclusion states: "It is very improbable that the minute quantity of organic matter contained in air expired from the human lungs has any deleterious influence upon men who inhale it in ordinary rooms, and hence it probably is unnecessary to take this factor into account in providing for the ventilation of such rooms." [10]

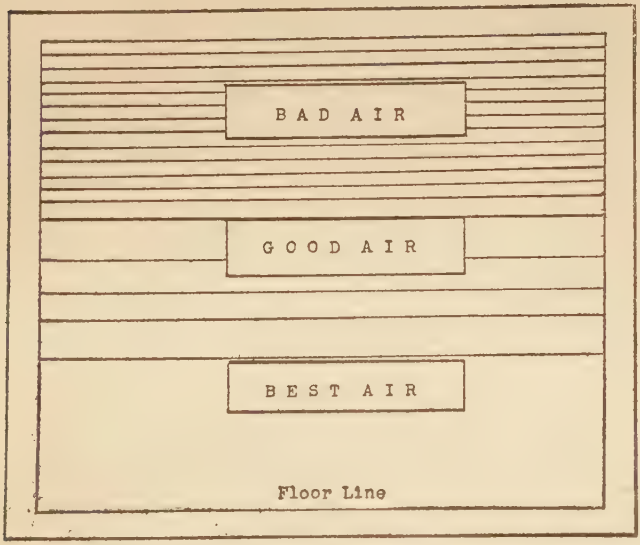
---

[9] *Ibid.*

[10] J. S. Billings, S. W. Mitchell and D. H. Bergey, "The Composition of Expired Air and Its Effects upon Animal Life," *Smithsonian Contributions to Knowledge,* Vol. 29, No. 989, p. 24.

Diseases Are not "Air-Borne"

Closely allied to the theory of and belief in "crowd poison" is the theory of "air-borne infection." This



Cross Section of a Room to Show Relative Strata of Best, Good and Bad Air

theory exerts much influence in the ventilation practices of to-day and is difficult to dislodge from the minds of individuals.

Chapin, a leading authority on public health, says there is evidence to show that the common diseases are not easily transmissible through the air. There

is every reason to think that disease germs rarely grow outside of a living body and that they are not likely to be dust-borne. "We are warranted in discarding it (the air-borne theory) as a working hypothesis, and devoting our chief attention to the prevention of contact-infection." [11]

Mouth spray from coughing and sneezing is dangerous only to those within direct range of it. Germs exposed to light and air quickly die.

Problem Is Physical and Not Chemical

Human occupancy is known to cause four general changes in the air of confined places: (1) the oxygen content is decreased; (2) the carbon dioxide content is increased; (3) the temperature is increased, and (4) the humidity is increased.

Prior to 1883, practically all hypotheses explaining the effects of poor ventilation were based upon the first two changes. Hermans in 1883 reported that the bad effects of the air of occupied rooms were due to excessive temperature and humidity. Billings, Mitchell and Bergey in 1895 announced the same conclusion. This was the beginning of the thermal theory (heating of air) which is the most scientific view of ventilation to-day. Experiments which prove its validity have been repeatedly

[11] Charles V. Chapin, *Sources and Modes of Infection* (John Wiley & Sons, Inc., New York, 1916), p. 314.

confirmed by scientists, both in this country and in Germany and England.

The most positive statement of this conception of ventilation comes from Leonard Hill of England and his associates in this field, who are regarded as outstanding authorities: "Heat stagnation is, therefore, the one and only cause of the discomfort, and all of the symptoms arising in the so-called vitiated atmosphere of crowded rooms are dependent upon heat stagnation." [12]

In 1914 Frederic S. Lee, an eminent American physiologist, said: "The physiological problems of ordinary ventilation have ceased to be chemical and pulmonary and have become physical and cutaneous." [13]

Air We Live in More Important Than Air We Breathe

We need to understand that air that is fit to breathe meets only one requirement. Air must be fit to live in. We are as definitely affected by the air surrounding us, which we do not breathe, as by the air we do breathe.

---

[12] Leonard Hill, M. Flack, J. McIntosh, R. A. Rowlands and H. B. Walker, "The Influence of the Atmosphere on Our Health and Comfort in Confined and Crowded Places," *Smithsonian Miscellaneous Collections,* Vol. 60, p. 92.

[13] F. S. Lee, "Physiological Problems of Ventilation," *Journal of Industrial and Engineering Chemistry* (1914), p. 247.

Hoobler has tabulated the qualities of air which affect the human body, and the body mechanism which is affected, as follows:

Functions of air due to its

Moisture
Temperature
Movement
Atmospheric pressure
Stimulating or depressing effect

Functions of the air—their effects on man as shown by changes in

Blood pressure
Pulse rate
Respiration rate
Metabolism
Nervous phenomena

All of the above have to do with the effect of air on the surface of the body and do not take into account the air in its function as a means of respiratory exchange.[14]

Hoobler points out that ventilating engineers have dealt with the environment rather than the man. They have seen a *room* to be ventilated; not

[14] B. Raymond Hoobler, "The Effect of Humidity, Temperature, Air Movement and Barometric Pressure on the Blood Pressure, Pulse and Respiration of Children under the Influence of Various Forms of Ventilation," *Transactions of the Congress of Hygiene and Demography* (Washington, D. C., 1912).

a *man* to ventilate. He calls attention to the mass of information with direct bearing on ventilation problems from calorimetry. "The classical standard for what seemed good ventilation has been overturned," he observes, "by the data obtained through observations made by means of the Atwater and Benedict calorimeter in this country, and through a similar apparatus in the hands of Flügge and his pupils of the Breslau laboratory."

Importance of the Surrounding Air to Body

"How does the air which surrounds us and which we may never breathe, act upon the body?" pertinently asks Hoobler. He then gives a picture of the functions the air performs aside from its use in respiratory exchange. It is important to reiterate these functions, since they form the basis for the new conception of ventilation.

The air absorbs the moisture which the body gives off constantly from skin and lungs (550 grains per hour). It carries off the excess heat which the body produces—500 B.t.u. (British thermal unit) for an adult and 200 B.t.u. for a child per day. By its variability the air plays upon the vasomotor apparatus, one moment opening the superficial capillaries and the next moment closing them in order to maintain circulatory equilibrium. By its function of motility the air breaks up the envelope

of vitiated air which tends to surround the body at rest. Fresh air constantly stimulates the body while superheated air depresses it.

Since the physiologists and health experts have entered the field of ventilation there is a decided tendency to make headway, especially in the interest of the health of school children.

Open Windows Best for Fresh Air

Many systems of ventilation have been tried but so far most of the mechanical systems of ventilation have failed to provide fresh air.

"Compulsory ventilation,"[15] the policy upon which the American Society of Heating and Ventilating Engineers launched several years ago, is a procedure probably without justification. In view of mechanical ventilating equipment failing to supply fresh air to enclosed spaces, it is only fair that any other method that will provide fresh air be recognized on its merits.

When engineers attempt to determine the percentage of perfect ventilation by means of an air chart in which temperature and air movement are rated on an equal basis with dust, bacteria, odors and carbon dioxide, it is obvious that the result will be misleading. No other quality of air can compen-

[15] Hugh J. Barron, *Transactions of the American Society of Heating and Ventilating Engineers,* Vol. 1, p. 196.

sate for a high temperature. If room temperature registers 75 degrees F. the air is no longer fresh, and to say it is 80 per cent perfect because of other conditions is gross error. Bacteria and carbon dioxide are entirely negligible. It is doubtful whether dust need enter into the consideration of the average room air from a health viewpoint. Schools now use dustless chalk almost uniformly. Also it is customary to oil schoolroom floors and to keep them clean by use of oil mops or scrubbing with soap and water. Dry broom sweeping is being supplanted by better methods.

After an exhaustive study of methods of ventilation, the New York State Commission on Ventilation declared in favor of window-gravity ventilation for schoolroom use.[16] The Commission's investigations were confined to schoolrooms.

After a study of the report of the New York State Commission on Ventilation, and following other reports and investigations and the testimony of the experience of members of its own group, the Joint Committee on Health Problems in Education of the National Education Association and the American Medical Association, endorsed "modified" window ventilation for schoolroom use. This was done two years after the report appeared.

---

[16] *Report of New York State Commission on Ventilation* (E. P. Dutton & Co., 1923), p. 528.

Health Committee Takes Action

For some years the Sub-Committee on Ventilation of the Joint Committee on Health Problems in Education of the National Education Association and the American Medical Association has made a study of heating and air conditions in schoolrooms, in the hope of finding a method which could be recommended to educational systems. Although specific instances of successful ventilation through simple, direct ways of admitting fresh air were convincing to the members of the Committee, they wished to gather sufficient evidence to warrant a recommendation of the general application of the method. The Committee feels that it is now in a position to make such a recommendation.[17]

Then follows a summary of the work of the New York State Commission on Ventilation, after which the Committee makes the following statement and recommendations:

After a careful review of the results of recent investigations in regard to ventilation of school buildings, the Joint Committee on Health Problems in Education of the National Education Association and the American Medical Association recommends modified window ventilation for school rooms, according to the method already outlined. These recommendations are based on the following facts:

---

[17] *Report of the Joint Committee on Health Problems in Education of the National Education Association and the American Medical Association* (February, 1925).

1. Window ventilation with gravity exhaust makes possible the degree of temperature, amount of humidity, amount of air movement desirable for schoolrooms.

2. The above characteristics of window ventilation with gravity exhaust are factors contributing to the health of occupants and to a lower incidence of respiratory diseases.

3. These characteristics contribute to comfort and a more attractive atmosphere.

4. Ventilation by windows according to the method described is more economical to install and should be more economical to operate than an artificial system.

To work satisfactorily, any plan must be under the attentive control of an intelligent, interested person.

In states where at present there are laws requiring 30 cubic feet of air supply per pupil per minute, the Committee recommends revision of legislation which will permit of window ventilation not now possible under such laws.

Endorse Window-Gravity Ventilation

The most recent as well as the strongest endorsement of window-gravity ventilation was that of the American Public Health Association at the Association's 1925 Convention in St. Louis, Missouri. These resolutions read:

Whereas, hundreds of thousands of dollars are wasted every year on this continent in the installation and operation of systems of school ventilation which are not only not beneficial but are positively harmful to the health of school children, and

Whereas, in the light of current knowledge, the supply of as large an air volume in schoolrooms as 30 cubic feet per minute, per capita, is necessarily accompanied with dangerous overheating of the schoolroom in order to avoid resulting drafts, and

Whereas, the use of ozone and other chemicals for treating schoolroom air has little or no scientific justification and little or no practical value, be it

Resolved, that the system of ventilating schoolrooms by fresh untreated outdoor air, admitted at the windows with gravity exhaust ducts for removing vitiated air from near the ceiling, is the most generally satisfactory method of school ventilation, be it

Resolved, that we recommend that state laws and city regulations interfering with such scientific and economical methods of school ventilation should be repealed in the interest of the public health.

Summary

Ventilation is the process or act of supplying fresh air continuously to enclosed occupied spaces.

The carbon dioxide theory dominates most mechanical ventilation practice to-day, although it was discredited sixty years ago.

There is no such thing as "crowd poisoning."

Diseases are not "air-borne." Mouth spray from coughing and sneezing is dangerous only to those within direct range of it.

Heat stagnation is the one and only cause of discomfort arising in a crowded room.

In ordinary ventilation, the problems are physical and cutaneous, and not chemical.

Air that is fit to breathe meets only one requirement; it must also be fit to live in.

"Compulsory ventilation" by mechanical means is not justified, in view of the failure of mechanical systems of ventilation.

Modified window ventilation is endorsed by the Joint Committee on Health Problems in Education and by the American Public Health Association.

CHAPTER IV

VENTILATION PRACTICES

"Standard" Ventilation Violates Scientific Principles

So-called "standard" ventilation which is in general use, especially in schools, draws outside air into a plenum air chamber, heats it to a temperature of 70 to 100 degrees F. and then drives it into rooms at high velocity by means of fans. The air thus supplied is admitted into the rooms about eight feet from the floor. "Standard" ventilation removes the "foul" air at the floor line. This system violates two scientific principles now well established in ventilation.

The attempt to supply a large quantity of air to a room is in recognition of the outworn theory of the harmful effects of carbon dioxide and of the so-termed "organic poisons" in expired air. By rapid displacement of breathed air, it is thought to remove this air and to dilute it with the incoming air, before it becomes harmful.

The removal of the "foul" air at the floor again assumes that carbon dioxide is heavy and falls to

the floor, and is the dangerous element to be dealt with in ventilation.

The volume of air which "standard" ventilation supplies is far more than is actually needed. The

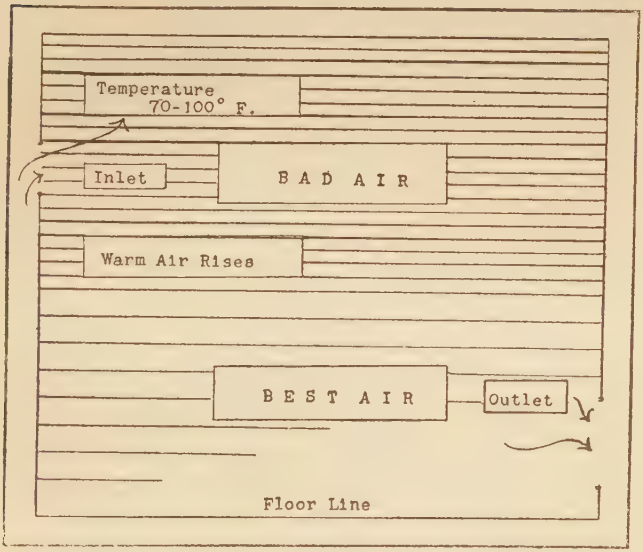


Diagram to Show How "Standard" Mechanical Ventilation Removes the Best Air from a Room

overheated air is the air we wish to get rid of, and since warm air rises, it is best to remove it at the highest point in the room.

The trunk duct system as contrasted with the individual duct system provides for the admission

of air of the same temperature to all rooms. The chief disadvantage of this system is that rooms on the sunny side of the building are subjected to the same temperature of air as that delivered to the other rooms. The individual duct system is a distinct improvement over the trunk duct system, since the temperature of air delivered to each room may be controlled separately.

Mechanical Systems Contrasted

Both the individual and the trunk duct systems of ventilation use radiators in the rooms for heating. The separation of the heating and the ventilating units in this manner is known as the "split" plenum fan system. In contrast to the "split" system is the all-blast system which has no direct radiators in the rooms, but accomplishes both heating and ventilating by means of fans or blowers which drive air through heating chambers and discharge it directly into the rooms.

Also in contrast to the "split" system is the "unit" system, a comparatively new idea in mechanical ventilation which may be called a modification of "standard" ventilation. The "unit" system provides for individual ventilating units in each room. The "units" contain radiators and electrically operated fans which draw air in from outdoors, heat and discharge it directly into the rooms. In addition

to the radiators contained in the ventilating "units," other radiators may be located in the rooms for heating purposes only. The "units" can deliver air into rooms at high velocity.

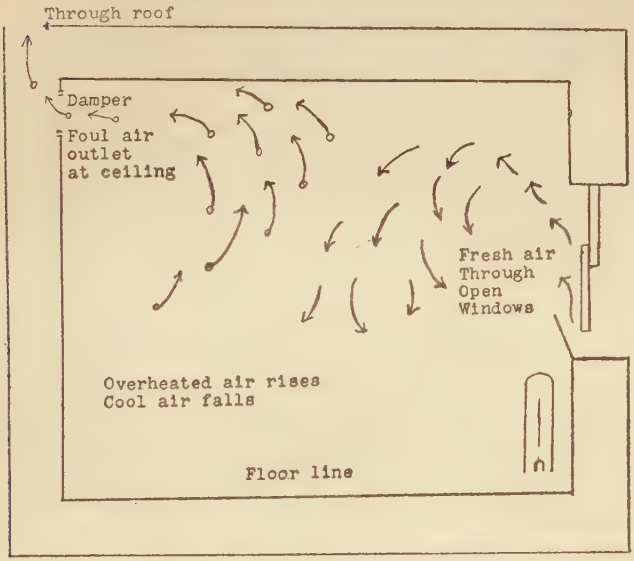


Diagram to Show Movement of Air Currents in a Room Ventilated by the Window-Gravity System

Recirculation of Air Economical

To constantly heat incoming cold air requires the consumption of large quantities of fuel and current. This has led to a complaint that mechanical ventilation is too costly to operate. It has been the reason,

in many instances, for the discontinuance of the operation of such systems. To meet this criticism the ventilating engineers have devised a plan for "recirculating" air. The exhaust ducts near the floor carry the air back to the plenum air chamber, and fans send it again to the rooms. Sometimes the air to be recirculated is passed through a fine spray or curtain of water for the purpose of cleaning and humidifying it. This is known as "washed air." It is said to remove the dust and soot, but some investigators claim that it does not remove soot.

Ozone Used to Destroy Odors

"Washing" the air does not always remove the odors, but may even aggravate them. Ozone, therefore, is resorted to in some instances for the purpose of removing odors. Ventilation ozonators are used. Their operation requires careful attention, for the peculiar smell of ozone is distasteful to many people. An overdose of ozone is harmful. The proof of the right dosage lies in the fact of its not being noticed.

The claims that ozone used in ventilation will destroy bacteria are disproved by scientific investigation. Ozone in the concentration that is breathable, about one part in 10,000,000, will not prove effective as a germicide.

Vosmaer says: "The object of ventilating with

THREE METHODS OF ADMITTING FRESH AIR.

Left, air to all parts of an office through outlets in a fresh air duct. Center, fresh air through duct concealed in base column supplied air rises through swivel nozzles seen at top. Right, swivel nozzles in ceiling outlet combined with lighting fixture.

ozonized air is not, in the first place, to try to kill bacterial life; the real object is to take away the bad odors and by so doing remove the uncomfortable feeling one experiences when remaining for a long time in a confined space." [1]

The New York State Commission on Ventilation regarded the use of ozone in ventilation as of doubtful value and withheld endorsement of recirculated air because of its discomfort possibilities.[2]

Fresh Air by Mechanical Means

A New York engineer has devised a system of ventilation which is mechanical, but which has for its object the delivery of fresh unheated air indoors, by means of ducts. In order to secure a fairly rapid movement of air, this engineer uses a fan to draw the fresh air inside. The ducts are equipped with swivel nozzles which diffuse the air. In large buildings these nozzles are furred into the distributing duct, one nozzle appearing every eight or ten feet. In the ordinary living room or office the nozzles appear in the ceiling above a central lighting fixture, or independent of such fixture if none is used. In order to temper the incoming air slightly, and also for the purpose of inducing

[1] A. Vosmaer, *Ozone: Its Manufacture, Properties and Use* (D. Van Nostrand Co., New York, 1916), p. 164.

[2] *Report of the New York State Commission on Ventilation* (E. P. Dutton & Co., 1923), p. 518.

a greater movement of air, electric heating coils are sometimes used adjacent to the nozzles.

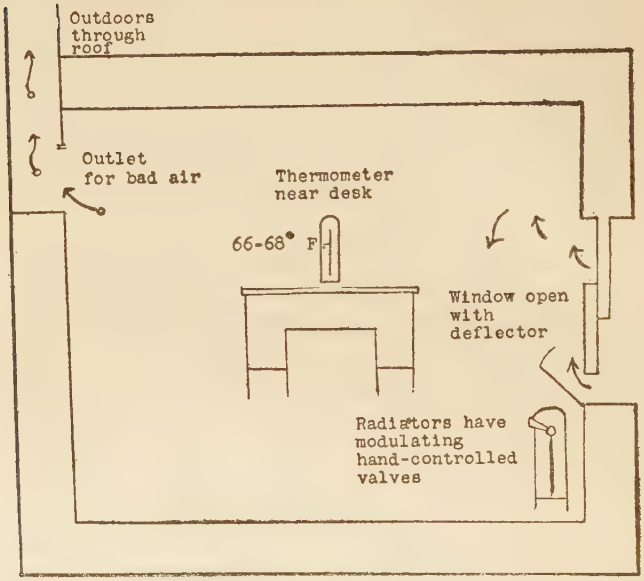


DIAGRAM TO SHOW HOW WINDOW-GRAVITY VENTILATION OPERATES TO REMOVE THE BAD AIR AT THE CEILING OUTLET AND TO ADMIT FRESH AIR AT THE BREATHING PLANE

The diagram shows position a thermometer should occupy in every schoolroom and emphasizes heat control from the room.

The air which is delivered to rooms through these ducts is first filtered through a processed fiber which is renewed each month, or more frequently, as nec-

essary. This removes dust, soot and smoke to a very considerable extent.

The promoters of this system of ventilation claim that the diffusion of unheated fresh air into the overwarm stratum at the ceiling makes it possible to maintain a uniform temperature from floor to ceiling.

Window-Window Ventilation Presents Difficulties

Ventilation, by cross currents of air from windows open on two sides of a room, or from windows open top and bottom, is still commonly used. It is used in smaller schools without mechanical systems. It is used in larger schools when mechanical systems are shut off. Homes use it almost entirely.

The chief disadvantage of this system is the fact that unless windows are high, odors and stuffiness are not thoroughly removed without producing drafts and chilling. Overheated air accumulates at the top of the room and extends down to the breathing plane, giving rise to a feeling of pressure about the head and the sense of stuffiness as the air is rebreathed. Usually the floors are cold.

Modified Window Ventilation the Best Practice

Modified window ventilation provides for the continuous admission of air through windows, although

openings may be very small in the coldest weather. The warm, breathed air is dismissed at the ceiling through a duct leading through the roof. The colder outdoor air being heavier, displaces the warmer and lighter air indoors. The admission of air at windows gives a gentle motion to the air in the breathing plane which is pleasant and stimulating.

The removal of the warm air at the ceiling outlet tends to keep the room cooler than otherwise. Another advantage of the exhaust ducts is the removal of odors.

Modified window ventilation is sometimes known as *window-gravity ventilation* or *natural upward ventilation.* The New York State Commission on Ventilation, experimenting with most of the common types of ventilation, both mechanical and non-mechanical, found window-gravity ventilation "the most generally promising method for the ventilation of the classroom where local conditions permit its use." [3]

Leonard Hill and his associates in England, in 1913, came to the same conclusion: "rooms should be heated by radiant heat and ventilated with cool outside air." [4]

---

[3] *Ibid.*

[4] L. Hill, M. Flack, J. McIntosh, R. A. Rowlands and H. B. Walker, "The Influence of the Atmosphere on Our Health and Comfort in Confined and Crowded Places," *Smithsonian Miscellaneous Collections* (1913), Vol. 60, No. 23, p. 93.

Survey of Ventilation in 879 Schoolrooms

An idea of ventilation practice in schoolrooms in various parts of the country is gained from a recently published study of child health conditions in 86 cities by the Research Division of the American Child Health Association.

School Ventilation Methods [5] Broadly Classified by Type and by Sections of the Country (855 schools in 84 cities)

Section	Number of Schools Visited	Per Cent of Buildings Ventilated by		
		Window Only	Window and Gravity Exhaust	Mechanical Equipment, Including Unit System
New England	124	14	56	30
Middle Atlantic ..	145	16	8	76
South Atlantic ..	110	73	4	23
East North Central	206	21	16	63
East South Central	55	49	29	22
West North Central	73	37	18	45
West South Central	33	88	9	3
Mountain	28	64	25	11
Pacific	81	58	1	41
Total	855	...	...	...
Average	...	37	18	45

[5] *A Health Survey of 86 Cities* (American Child Health Association, October, 1925), p. 193.

It was observed that windows were open in one-third of the mechanically ventilated schoolrooms, showing that the teachers were not satisfied with the air conditions provided and were making attempts to secure better ventilation.

Summary

The principles which govern so-called "standard" mechanical systems of ventilation are derived from outworn theories.

Emphasis is wrongly placed on air velocity and air change rather than upon temperature and freshness.

Mechanical ventilation is expensive to operate because it takes much fuel to heat large quantities of cold air; hence a system of recirculated air has been devised which is more economical.

When air is recirculated it is passed through an "air washer" for the purpose of removing the dust and soot.

Moistening recirculated air does not remove the odors but rather aggravates them so that ozone is applied sometimes for the purpose of masking the odors.

There is a possibility of applying an overdose of ozone in treating air, and this would be dangerous to health.

An improvement over mechanical, so-called "standard" ventilation blows a small quantity of unheated outdoor air into rooms at the ceiling.

Cross ventilation by means of windows, unless very

high, may cause objectionable drafts and schoolrooms so ventilated are not relieved of odors.

Modified window ventilation which admits fresh air at the windows and dismisses overheated air at the ceiling is regarded the most satisfactory for schoolroom use by the New York State Commission on Ventilation.

English scientists say that rooms should be heated by radiant heat and ventilated with cool outside air.

In a survey of 879 American schoolrooms, mechanical ventilation was used in 45 per cent of these schools; 37 per cent used windows only and 18 per cent had window-gravity ventilation.

CHAPTER V

VENTILATION LAWS

Outworn Theories Form Basis for Ventilation Laws

ALTHOUGH fresh air is rarely found in enclosed places, the desire for it is so great that laws have been passed with a view to making ventilation compulsory. When the ventilating engineers proposed the legal requirement of a minimum of 30 cubic feet of air per minute per person, this was considered by most health workers and by the public in general as a wise provision. It was recognized that more fresh air was needed.

It is not generally known, even to-day, that this law is based upon the outworn theories of harmful impurities in expired air. Ventilation laws fail entirely to take *low temperature* into consideration. In fact, to supply a room with as great a volume of air as the law requires, usually necessitates that this air supply be heated to 75 or 100 degrees F. before it is admitted into the rooms, so that a chilling effect will be avoided.

This law operates to destroy the most important qualities which air, to be fresh, must possess. Overheating results in reducing the relative humidity, which makes the air dry instead of moderately moist. Where recirculation is practiced and air-washers used, the relative humidity may be sufficient but the odors then accumulate. Mechanical ventilation does not provide the variability which is characteristic of fresh air.

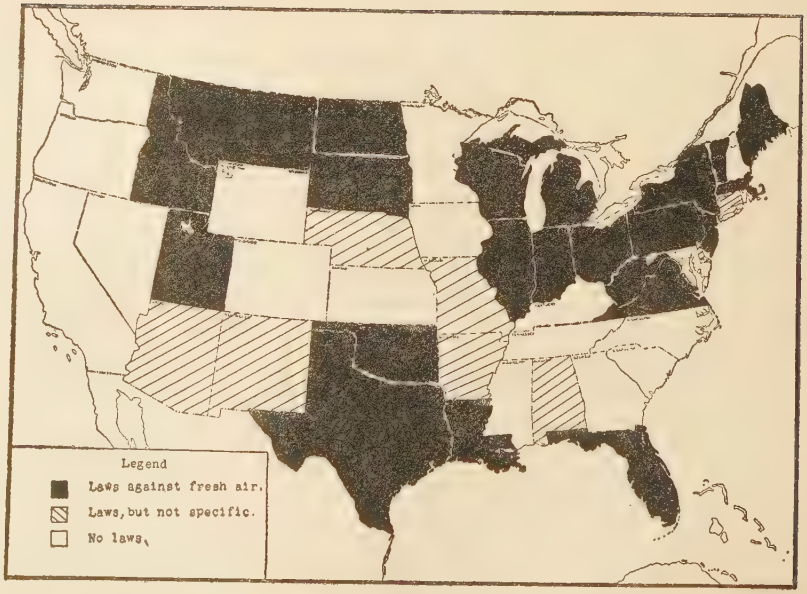
Twenty-four States Legislate against Fresh Air

In adopting the regulation that 30 cubic feet of air per minute per pupil shall be supplied to schoolrooms, nearly one half of the states have legislated against fresh air for school children.

Seventeen states, Winslow[1] points out, have no general ventilation requirements; seven have vague general provisions and twenty-four have specific laws or regulations. "In nine instances the standard is set by statute law; in eight by rules of the State Department of Education; in four cases by rules of the State Department of Health; in two by the Industrial Commission and in one by the Department of Public Safety.

In all of these 24 states, except Alabama, Ohio, Minnesota and Wisconsin, the standard which is set, spe-

[1] C.-E. A. Winslow, "The Dead Hand in School Ventilation," *American School Board Journal* (June, 1925), p. 45.



MAP SHOWING STATES WITH VENTILATION LAWS WHICH MAKE FRESH AIR IMPOSSIBLE FOR SCHOOLROOMS

Since this chart was prepared, the state of Virginia has modified its ventilation law and some other states are contemplating a similar action.

cifically calls for an air supply of 30 cubic feet per minute. In Ohio six changes of air per hour are required which, under ordinary conditions of occupancy, would amount to the same thing. In Alabama and Minnesota the figure set is four air changes per hour, which would require 10 to 15 cubic feet per minute per person. In Wisconsin the standard is two cubic feet per minute per square foot of floor area, which would generally amount to over 30 cubic feet per minute. This Wisconsin Code (drawn up by the Industrial Commission less than two years ago) is perhaps the most vigorous set of regulations anywhere in force. It not only requires that "positive ventilation" be "provided and maintained," but specifically prohibits "gravity direct-indirect systems," a term which, as I interpret it, includes the new systems now considered most generally satisfactory for the ventilation of the average schoolroom in the light of modern knowledge.

While this remarkable Wisconsin Code seems to allow no exceptions, it should be noted that many of the regulations discussed above are not of universal application within the respective states. The Alabama rule, for example, applies only to rural schools; the New York law excludes first and second class cities; the Utah regulation applies only where mechanical or gravity ventilation is used; the West Virginia provision applies only to "artificial ventilation systems." On the other hand the large cities have in most instances specific regulations of their own along the same lines.[2]

---

[2] *Ibid.*

STATUS OF LEGISLATION GOVERNING SCHOOL VENTILATION, AS OF JANUARY, 1925[3]

State	None	Legal Provision General	Specific
Ala.	..	..	R(E)
Ariz.	..	R	....
Ark.	..	R	....
Cal.	X	..	....
Colo.	X	..	....
Conn.	..	L	....
Del.	..	L	....
Fla.	..	..	R(H)
Ga.	X	..	....
Idaho	..	..	R(E)
Ill.	..	..	R(E)
Ind.	..	..	L
Ia.	X	..	....
Kans.	X	..	....
Ky.	X	..	....
La.	..	..	R(H)
Me.	..	..	R(E)
Md.	X	..	....
Mass.	..	..	R(PS)
Mich.	..	..	R(E)
Minn.	..	..	R(E)
Miss.	X	..	....
Mo.	..	R	....
Mont.	..	..	L
Nebr.	..	R	....
Nev.	X	..	....
N. H.	X	..	....
N. J.	..	..	R(E)
N. Mex.	..	R	....
N. Y.	..	..	L
N. C.	X	..	....
N. Dak.	..	..	L
Ohio	..	..	R(I)
Okla.	..	..	L
Ore.	X	..	....
Pa.	..	..	L
R. I.	X	..	....
S. C.	X	..	....
S. Dak.	..	..	L
Tenn.	X	..	....
Tex.	..	..	L
Utah	..	..	R(E)
Vt.	..	..	R(H)
Va.	..	..	L
Wash.	X	..	....
W. Va.	..	..	R(H)
Wis.	..	..	R(I)
Wyo.	X	..	....
Total	17	7	24

L=Statutory provision.
R=Regulation of educational authorities (E).
Health authorities (H), Industrial commission (I), or Department of Public Safety (PS).

[3] *Ibid.*

The law which was originally adopted for the purpose of supplying fresh air operates to defeat its own purpose and therefore should be abolished.

Present Standard Meaningless

It would be safe to say that approximately one half of the schools built in the United States are to-day constructed under the official regulations requiring the installation of systems of ventilation capable of supplying 30 cubic feet of air per minute for each child —which means, of course, systems of fan ventilation. Yet this whole complex legal and administrative structure rests upon the fundamentally erroneous conception that the object of ventilation is to dilute non-existent organic poisons.

The proper basis for estimating the adequacy of ventilation must be sought in a consideration of the problem of heat removal; and it is obvious that so far as heat removal is concerned external atmospheric conditions will affect it so materially as to make any rigid mechanical standards of air flow quite meaningless. Under certain conditions the standard of 30 cubic feet per minute may very well represent the true needs of the situation.

The fact is that while 30 cubic feet per minute may be set as a rough standard sometimes desirable to attain in very large rooms with slight heat loss, it may be insufficient in certain cases and in many other cases it is an unnecessarily high figure. Hygienists must insist on standards of air conditions actually maintained, rather than on any arbitrary mechanical standards assumed to be capable of maintaining them.

Any system which does not guard against overheating is inadequate, however large a volume of air may be forced into the room, and a system may be entirely adequate which supplies 10 cubic feet of air per minute if the temperature be properly regulated.[4]

Inconsistencies in Laws

Referring to the standard of 30 cubic feet of air per minute per pupil, McLure[5] says:

> It is startling but nevertheless it is a fact that, in spite of forty years of accumulated knowledge and especially fifteen or twenty years of overwhelmingly convincing evidence, approximately twelve millions of public elementary and secondary school pupils attend school every day in states having these archaic laws and regulations on school ventilation! This number represents more than half of all the pupils in the public elementary and high schools of the United States.

In further comment on the existing laws, McLure calls attention also to the fact that the law requiring 30 cubic feet of air per minute per pupil often does not apply to rural schools and sometimes not to one-story schools and small buildings. He points out that overcrowding exists in such schools as often as in the larger schools and

---

[4] C.-E. A. Winslow, *Fresh Air and Ventilation* (E. P. Dutton & Co., 1926), pp. 95–96.

[5] John R. McLure, "School Sanitation from the Standpoint of the School Administrator," address before American Health Congress, Atlantic City, N. J., May 20, 1926.

wonders why these supposed safeguards are denied the children attending the smaller schools. Again he finds that the laws are framed and administered so that the element of compulsion applies only to the installation of ventilation systems. "We have compulsory installation but no compulsory operation," he comments, and continues, "If the dangers of exhaled air in occupied rooms had proved in practice to be anything like as great as the advocates of mechanical ventilation have claimed, we would not expect to find such glaring omissions and inconsistencies in these ventilation laws and regulations."

It is consideration of such facts as these, accentuated by active dissatisfaction with the actual results of fan ventilation in schools [says Winslow] [6] which has led, during the past ten years, to a revival of interest in the system of gravity ventilation. The main reason for the appointment of the New York State Commission on Ventilation and the support of its work by the Milbank Memorial Fund was the desire to discover in the light of modern physiology whether the widespread criticism of fan ventilation, as officially enforced by lawmaking bodies, was justified and whether gravity ventilation or some other procedure could be substituted for it with advantage, under any or all conditions.

---

[6] C.-E. A. Winslow, *Fresh Air and Ventilation* (E. P. Dutton & Co., 1926), pp. 95–96.

Conspire to Defeat "Upward" Ventilation

But a regulation which is considered by some even more vicious than the "30 cubic feet per minute per pupil" standard is that which requires that the outlets for foul air for schoolrooms shall be placed near the floor. This regulation has been passed in Massachusetts and in some other states. It is said that there is an active propaganda for it in every state, furthered by those who believe that good ventilation can be had only by mechanical systems. The effect of such a regulation again is to make compulsory the so-called "downward system of ventilation," which is the mechanical ventilation, window-gravity ventilation being considered the "upward system."

To draw out air at the floor is to ignore the modern scientific principle that the overheated air is the undesirable air. Floor exhaust recognizes the outworn theory that carbon dioxide is the dangerous element in expired air and therefore must be removed at the floor since it is known to be heavier than air. Aside from the fact that it has been proved that the carbon dioxide content in the air of the most crowded room is harmless, it is claimed by scientists to-day that when the air of the room becomes overheated the carbon dioxide tends to rise, so that it is no longer at the floor line where the

exhaust has been placed to remove it. Also at the time it is exhaled, carbon dioxide is warmer than room air and is expanded enough to rise. So the floor exhaust outlet accomplishes nothing except to remove the best air of the room, which is the cool air.

Organized effort in support of the downward system of ventilation has been sharpened by the fact that when a fan is used in the outlet duct of upward ventilation, it is possible to maintain an air flow through a room which will comply with the law demanding an air movement of 30 cubic feet per minute. Finding that the enactment of one law would not check the development of upward ventilation, those interested in mechanical systems of ventilation urge the adoption of another which they believe to be a "sure kill" for window-gravity ventilation.

Fan-gravity systems, when experimented with by the investigators of the New York State Commission on Ventilation, were found to produce drafts, just as do the mechanical ventilation systems which endeavor to deliver a volume of 30 cubic feet of air per minute per pupil, unless such air is heated to a temperature higher than the health standard of 68 degrees F. permits.

The laws or regulations which require a floor exhaust should be abolished because unscientific and

because this method does not provide the best air in schoolrooms.

Cities in Grip of "Obsolete Standard"

That, in general, the cities of the United States are firmly in the grip of an "obsolete standard" of school ventilation so far as the installation of mechanical equipment is concerned, is the belief of McLure[7] as a result of his survey. "Since millions of school children in America have been provided with mechanical ventilation equipment," he states, "it is pertinent to inquire to what extent these ventilating systems are actually operated after they are installed." Since the use of the equipment is not compulsory, the extent to which mechanical ventilation is actually operated is a good measure of the estimate which is placed upon it by those who have had experience with it and who are supposed to benefit by it.

Then comes the revelation from McLure's study that mechanical ventilation is rarely operated outside of the heating season and that often in the heating season it is operated only as an adjunct to heating. "Evidence gathered on operating policy," reports McLure, "shows that systems of mechanical

[7] John R. McLure, "School Sanitation from the Standpoint of the School Administrator," address before American Health Congress, Atlantic City, N. J., May 20, 1926.

ventilation, when they are operated, are operated primarily for heating purposes and not for ventilation. In a certain sense, then, instead of having mechanical ventilation we have auxiliary heating. It appears that mechanical ventilation in the schoolroom is largely an engineering fiction."

McLure goes on to show a still more appalling condition: that in the new school buildings direct radiation is placed in classrooms in sufficient installations to maintain the required temperature without the use of the ventilation system. In these instances he claims that it is safe to conclude that the installation of mechanical ventilation is largely to satisfy the law or tradition and that there is no intention to operate the system after it is installed. Such a situation seems to be the case in New York City, he affirms.

"Code" Deals in Nonessentials

Describing the proposed "Code of Minimum Requirements for the Heating and Ventilation of Buildings" of the American Society of Heating and Ventilating Engineers, McLure observes that the Code does not declare boldly for the standard of 30 cubic feet of air per minute but rather has incorporated or endorsed a so-called "Synthetic Air Chart." "The significant thing about this 'Synthetic Air Chart,'" says McLure, "is that it pro-

poses standards not only in terms of temperature, humidity and air motion, but also in terms of dust, bacteria, odors, and carbon dioxide. Thus an engineering organization expects to tell the public what are the desirable conditions for the health of school children, while basing their standards upon several factors discredited by decades of research." He then states the essentials of the problem thus:

"The question may well be asked, 'Is it for the public good that heating and ventilating engineers now take over functions hitherto left by common consent to eminent sanitarians and authorities on health?" McLure concludes: "When it comes to a choice between a standard of health proposed by the ventilating engineer on the one hand and the public health authority on the other, the public health authority must be followed." [8]

The active interest of ventilating engineers and of manufacturers of ventilation equipment is largely responsible for the continuance of these outworn methods of ventilation. McLure says: "There is some evidence that the art of mechanical ventilation in some respects has been developed for its own sake." [9]

---

[8] *Ibid.*

[9] J. R. McLure, *The Ventilation of School Buildings* (Teachers College, Columbia University, 1924), p. 113.

Law Does Not Mention Windows

Although the law does not specify that windows may not be opened, it operates to that effect. With mechanical ventilation, windows cannot be opened without interfering with the operation of the fan system. Due to repeated complaints of teachers and of parents in regard to the overheated schoolrooms, some cities have adopted a ruling that windows may be opened if the temperature exceeds 75 degrees F. Also many schools now make a practice of opening windows whenever practicable, as at recess and at the noon hour.

Wherever mechanical ventilation is in use, teachers lodge their greatest complaint against the opposition they receive to opening windows. On the other hand, the ventilating engineers claim that the fact that teachers will open windows in spite of the rules, has operated to make the system of ventilation ineffective.

One New York School principal was asked if she had good ventilation in her school. "Yes," she replied, "when we shut off the mechanical system and open our windows."

Factory Laws Ineffective

Factory laws in regard to ventilation usually provide that certain specified cubic contents of working

space be allowed each person employed, and then add a phrase to the effect that "adequate ventilation be supplied." This leaves the question of ventilation very largely in the hands of the foremen, with the result that factory ventilation in the main is no better than school ventilation. A few progressive manufacturing plants have taken steps to secure modern scientific ventilation, as described in Chapter VII.

Theaters and public halls in some states are required to provide a certain air change for the seating capacity. In no theater ventilated by mechanical equipment of the "standard" type does it seem possible to keep the temperature within the health safety zone, without making patrons uncomfortably cold and subjecting them to uncomfortable drafts.

New York's Subway Requires Open Windows

Street cars, subways and Pullman cars are often required by city ordinance or state law to provide ventilation for passengers. In these cases, usually window ventilation is prescribed. New York's subway trains are required to keep windows open winter and summer. As a result, subways often are surprisingly well ventilated, except in the warm weather with high temperatures, when, even with fans running, they are stifling.

Pullman cars vary in their ventilation according

to the interest and desire of the passengers to secure good air. Too often the temperature is higher than safety or comfort permits. A thermometer should be placed in every Pullman car and a porter instructed to keep the temperature below 68 degrees F. during the day, and still somewhat lower at night.

Cities and States Have Ventilation Codes

Temperature is the first consideration in the Ventilation Code adopted by the Department of Health of New York City, December 11, 1917. It reads:

> The temperature in rooms during occupancy should register preferably from 60 to 70 degrees F. at all times, except when the outside temperature exceeds 60 degrees F. This does not apply to rooms used for special purposes, such as industrial places where high or low temperatures are essential and unavoidable.

It is self-evident that such a law cannot regularly be enforced but, nevertheless, it serves an educational purpose.

The newly adopted Heating and Ventilating Code of the State of Wisconsin strikes one scientific note, at least, when it calls for the display of thermometers:

> A reasonably accurate thermometer shall be provided and maintained for each 1000 square feet or fraction, in all occupied areas having more than 350 square feet floor area, and shall be easily accessible

and properly located to show temperature of the zone served.

Temperature, the most important consideration in ventilation, is not mentioned. Not even a suggestion is given to schools; nor is it required that records be kept of thermometer readings in schools or elsewhere. Perhaps the Code contemplates one step at a time. Surely to secure the thermometers is a forward step.

Summary

Ventilation laws which require 30 cubic feet of air per minute per pupil are based on the discarded carbon dioxide theory. Such laws fail to take temperature into consideration as the most important element in ventilation.

Ventilation laws or regulations which require the exhaust to be at the floor, violate the scientific principle that the overheated air is the air to be removed and that consequently the exhaust outlet should be at the ceiling rather than the floor.

Present legislation in regard to ventilation, until repealed, presents an insurmountable obstacle to progress toward the newer scientific practice.

Investigation shows that although school boards are complying with the laws in installing mechanical ventilation equipment, such equipment is largely idle except in the heating season when it is used as an adjunct to heating rather than for the purpose of ventilation.

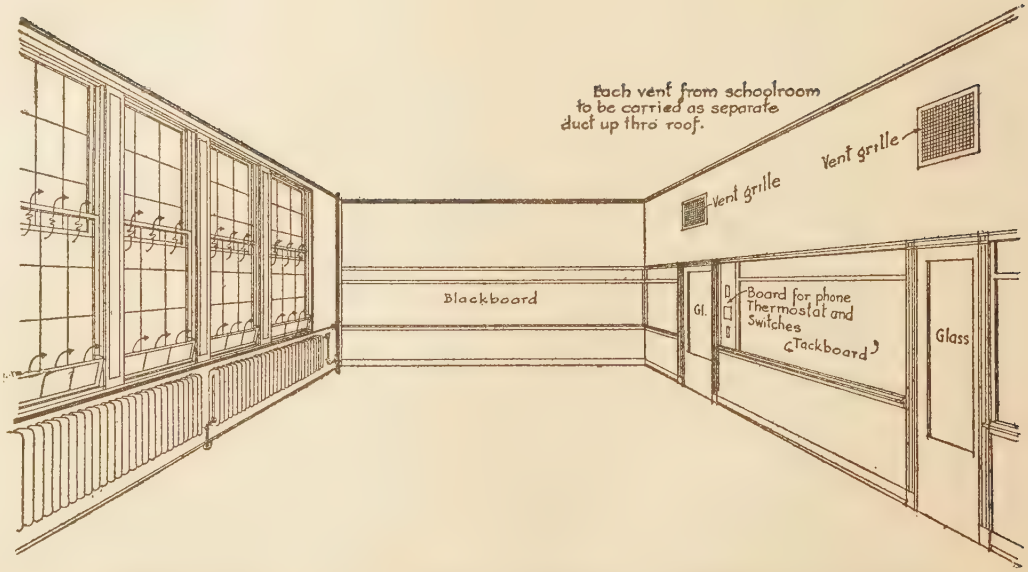
CHAPTER VI

WINDOW-GRAVITY VENTILATION IN SCHOOLS

Open-Air Schools Point the Way

MODIFIED window ventilation to a certain extent is indebted to the open-air school for its inspiration. More than fifteen years ago, when health workers saw the good effect of fresh air upon the pale, sickly children who were treated in open-air schools, the cry went up, "Why not have fresh air for all school children?" The story of the little boy in the open-air school who brought his pal to the school doctor and begged wistfully for his admission to the open-air class with the words, "Doctor, how sick does a feller have to be to get into the fresh-air school?" has become classic.

Not only do children like the open-air schools, but teachers thrive in them as well. Teachers in less robust health often are favored for open-air school positions. Many such teachers have had their lives prolonged by the fresh air. The fact that the open-air school is a recuperating station for both pupils and teachers who have been weakened and made ill by the overheated, dry air of the ordinary school-



INTERIOR VIEW OF TYPICAL CLASSROOM VENTILATED BY WINDOW-GRAVITY SYSTEM
(Courtesy Frank Irving Cooper Corporation)

room, has called attention to the need for fresh air in all schoolrooms.

A School Principal Opens Windows

William E. Watt was principal of the Graham School in Chicago in 1909, when the Elizabeth McCormick Memorial Fund established an open-air school on the roof of that school building. Mr. Watt watched its progress with interest. He was amazed to see the improvement in health which the children experienced after a few months in cold air. He went from the cool, pleasant temperature of the open-air school into the overheated, unpleasant temperature of the ordinary schoolrooms, and in doing so noticed the difference in the children. "Those children on the roof are alert and happy," he observed; "these indoor children are restless or drooping, and not markedly happy. I believe all school children should have fresh air," he concluded, and then, being a man of action, he resolved to try to get it for them. Several of his teachers were eager to coöperate with him.

"We can't provide all school children with Eskimo suits and extra lunches such as the open-air school children have," said Mr. Watt, "so we'll try to keep the temperature just warm enough so that extra clothing will not be necessary."

Believing that the outdoor air contains a liveness

which indoor air does not possess, Mr. Watt determined that all schoolrooms must be supplied with fresh outdoor air through windows. In winter he lowered the windows slightly from the tops, not enough to create a draft. These high openings also allowed the overheated air at the top of the room to pass out.

The experiments were tried in a few rooms at first and then extended. Parents were not uniformly convinced that they wanted their children to sit in cool air. Only those children whose parents asked for it in writing were placed in the cool rooms. Immediately the cool-air rooms were very popular with both pupils and teachers. The temperature voted the most satisfactory was around 60 degrees F. though several rooms preferred temperatures even lower.

Cool Air as Beneficial as Cold Air

The most gratifying results of the fresh-air rooms were found in the improved health and in the more satisfactory school progress of the children. It was a significant contribution to the general health movement to discover that children were benefited quite as much in cool-temperature rooms, 60 to 65 degrees F., as in the colder temperatures maintained by the open-air school where extra wraps and hot lunches were necessary. Children no longer need be impris-

oned in overheated schoolrooms which rob them of their vitality and make their studies more difficult. They had fresh, outdoor air, heated only to a pleasant degree and resembling mild outdoor weather.

Mr. Watt resigned his position as principal and began to crusade for fresh air for all school buildings. But it was not easy to upset the theories which had controlled ventilation practice for so many years. Furthermore, the law which requires 30 cubic feet of air per minute per pupil for every schoolroom, constituted a mandate for mechanical ventilation. Ventilating engineers were opposed to anything except mechanical ventilation. School boards usually were disposed to follow the advice of ventilating engineers. Some schools were eager for the open-window system.

Our Lady of Sorrows, a parochial school in Chicago, adopted window-gravity ventilation. The high school at Glenellyn, a suburb of Chicago, has it, and recently the Board of Education at Evanston, Illinois, installed it in all the schools of that section, another suburb of Chicago.

School Has Scientific Ventilation

One of the authors visited Our Lady of Sorrows parochial school in February, 1922, in company with the late Mrs. Ira Couch Wood, then director of the Elizabeth McCormick Memorial Fund. Room after

room was visited, and, although the outside temperature was just above freezing, the temperature of the schoolrooms was found to be from 60 to 65 degrees F. and in no instance was it higher than 65 degrees F. The air in room after room was fresh and delightful; the children and teachers were alert and cheerful with a healthy rosy color in their cheeks and a brightness, not usually seen in the eyes of indoor workers or students. The children did not wear extra clothing but quite apparently were comfortable in light-weight clothing. The girls for the most part wore gingham dresses and the boys wore light colored blouses. The teachers, of course, wore the usual habit of their church order.

"How do you secure this delightful atmosphere, this sweet-smelling, fresh air?" we asked. We were shown the openings, very slight openings, at the tops of most of the windows. As the windows were very high the cold air which entered had ample time to diffuse with the warm air of the room before it reached the pupils.

We saw the outlet duct near the ceiling, and observed, when a thin sheet of paper was raised before it, that air was moving upward and out of the room. "We close the opening into the duct with this shutter in cold weather when the room is not in use," explained the teacher, demonstrating its operation.

Exhaust Ducts in Wall Opposite Windows in Sherman School, Fairfield, Connecticut.

Notice position of flags showing air movement.

Windows Set for Late Fall Ventilation in Schoolroom at Evanston, Illinois.

Watt system of window-gravity ventilation.

Then she showed us a simple valve attached to the supply pipe which brought steam to the radiators. "We turn this on before the session opens in the morning, at recess, in the middle of the morning, and again at noon." She demonstrated for a moment, letting the live steam hiss and sputter into the room, its vapor spreading in all directions.

So that was the whole secret of the freshness of the air in these rooms! no, not quite all. We were told that the engineer or janitor was careful to observe weather reports, and that he did not overheat the rooms but endeavored to deliver just the proper amount of heat needed. There was a thermometer in every room and the teacher read this every few hours, and if necessary turned off the heat in the radiators. They said that usually they did not need to change the window openings from the way the janitor set them in the morning.

"Smell of the Elephant" Absent in Window-Gravity Schools

"Well this is the first school I have ever been in where one did not smell the elephant!" exclaimed one of the visitors, and repeated the story told by a school principal: "The kindergarten planned a menagerie. Mothers and younger brothers and sisters were invited. When Johnny arrived with his mother and they entered the school from outdoors,

Johnny exclaimed, 'Oh, they are having the menagerie, mother; I can smell the elephant!' "

Every one can "smell the elephant" upon entering the average school building. But teachers and pupils who spend so much time there become oblivious of the odor. It has not been fully realized that such odors may be avoided by proper ventilation. They do not exist in schools ventilated by a correctly operated window-gravity system.

Samuel H. Wheeler's Important Work

While Mr. Watt was working out window-gravity ventilation in Chicago, the late Samuel H. Wheeler was experimenting with a similar system in Connecticut. The Sherman School, in Fairfield, Connecticut, is known as the home of the Wheeler system; although the first experiment was conducted in the Longfellow School in Bridgeport. But whereas Bridgeport has been slow to adopt window-gravity ventilation for other schools, Fairfield has installed it in every school constructed since 1913, when it was first introduced. The superintendent of schools of Fairfield is enthusiastic in his endorsement of the system. He believes it the most efficient and economical plan of ventilation yet devised.

In the Sherman School, windows are placed only on one side of the rooms, so that the children receive the light from the left. Mr. Wheeler was interested

in lighting as well as in ventilation. The windows are of the double hung, vertically sliding design, believed to be the best for ventilation. They operate readily so that even a child can raise and close them easily. But whereas Mr. Watt opened windows from the top, Mr. Wheeler opened them from the bottom and used deflectors to prevent drafts. In his first experiments, Mr. Wheeler used an adjustable deflector made of glass with a wooden frame. But later he adopted a stationary type of deflector about 10 inches high which he found practicable. In operating for the best ventilation results, each window is opened slightly, so that air, coming in at various places, will be readily warmed and diffused. Radiators under the windows and extending beyond them, warm the air sufficiently, as it enters, so that there is no draft (see illustration).

Near the ceiling, in the wall opposite the windows, and toward the end of the wall so that there is a wide space between them, are two outlets having a possible opening 18 inches square. They lead upward and through the roof. A sliding window is fitted over each so that the outlet may be closed when the room is not in use. In front of each outlet may be seen a small silk flag. By this signal, one is constantly assured that air is moving up and out of the room through the duct. In each room a thermometer is placed on the wall near the teacher's

desk away from the windows. Mr. Wheeler found that a temperature fluctuating between 64 and 68 degrees F. was best.

Teachers in the Sherman School express complete satisfaction with the system of ventilation. One teacher claims that her health has improved markedly since she has taught in rooms ventilated with fresh outdoor air.

Comparison of Fan and Window Rooms

The Longfellow School in Bridgeport was visited in late November, 1925. Here one sees the first example of window-gravity ventilation in Connecticut. Within a block of this newer school is an old building ventilated by the fan system. The same principal supervises both schools. She took her visitors first to the window-gravity rooms in the Longfellow School, where the room temperatures were found to be 68 degrees F. These rooms were fresh and sweet smelling, although the air seemed somewhat too warm upon entering the first room from outside.

Later the fan-ventilated rooms in the old building were visited. Oddly enough the temperature in these rooms was 68 degrees F., also, as indicated by the thermometers. But what a difference! The air, instead of smelling fresh, as one entered from the outside, seemed musty and unpleasant. It was stagnant. Here was an instance where the air that

was blown into the room was not overheated and yet it lacked the quality of fresh air.

The principal expressed complete satisfaction with the window-gravity rooms, but was dissatisfied with the fan-ventilated rooms.

Two Systems of Window-Gravity Ventilation Contrasted

Although the Watt and the Wheeler systems of ventilation contribute to the same end, there are slight differences in them.

Equipment

The Wheeler System	*The Watt System*
Radiators to be located beneath windows and extend more than the full width of windows.	Half as much radiation as ordinarily is provided.
Modulating hand-controlled valves on all radiators, as well as intermediate acting thermostat for automatic control; either of which presupposes the use of vapor vacuum steam-heating system.	Same.
Radiator shields.	Insulation of radiators to prevent heat escaping through outside walls. Sometimes uses shields.

The Wheeler System	*The Watt System*
Deflectors. Glass deflectors 10 to 12 inches high.	No deflectors.
Double-hung vertically sliding windows.	Same.
Windows open at bottom.	Windows open at top.
Window shades set in center of window to roll each way.	Window shades set a few inches down from the top to prevent flapping when windows are open at top, or center set.
Exhaust ducts, area 18 inches square.	Exhaust ducts, area 8 to 12 inches square.
Dampers to control ducts.	Same.
Thermometer prominently displayed.	Same.

Operation

Temperature standard 65 to 68 degrees F.	Same.
Heat rarely to be turned off. Windows to be opened wider as more cool air is required.	Heat turned off or diminished as soon as room is warmed.
No attention given humidity.	Humidification by live steam during the heating season.
Janitor instructed to fire heavily in cold weather.	Janitor instructed never to fire heavily and to keep fires checked when rooms are warmed sufficiently.

Architects Design Window-Gravity Ventilation

School architects in increasing numbers are now taking active interest in the widow-gravity system of ventilation. The Frank Irving Cooper Corporation, of Boston, is among the firms which have used the system successfully. Mr. Cooper was a warm personal friend of the late Samuel H. Wheeler. Both men held the same views in regard to ventilation.

Mr. Cooper states that while he is satisfied that the law which requires 30 cubic feet of air per minute per pupil is in excess of the health needs of children, he has met the requirements of this law with window-gravity ventilation. Where the movement of air is not sufficient by means of gravity alone, a fan is used in the exhaust flue. The use of a fan causes a more rapid movement of air and protects from drafts which sometimes sweep down through the flue.

In order to induce a greater air movement, Mr. Cooper also places the steam supply pipes over the radiators and just under the window deflectors. This supply pipe is intended to carry steam at all times in the heating season. Contact with the warm air about this pipe causes incoming air to be diverted upward at the times when the radiators themselves are not heated.

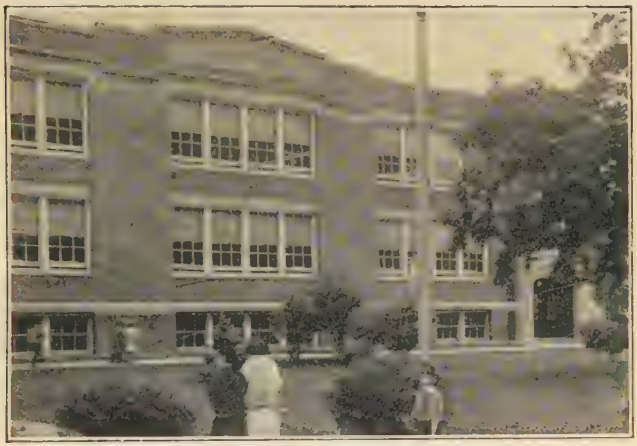
One of the largest schools in the country to be ventilated by window-fan-exhaust (operating on the same principle as window-gravity) ventilation is the Thomas Snell Weaver High School in Hartford, Connecticut. Mr. Cooper is the architect of this school. Other schools in New England which have window-gravity ventilation include several buildings in Stratford, Connecticut; the new high school at Enfield, Connecticut; and the Coleman Street School, Gardner, Massachusetts.

Window-gravity ventilation has been installed successfully by architects in schools in Kansas City, Kansas, and in Birmingham, Alabama.

Although window-gravity ventilation can be installed in any school already constructed, it is more readily installed in new buildings. Window ventilation works to best advantage when the building is designed with this in view.

Ducts and Their Importance

The size of the exhaust duct has occasioned some discussion. The New York State Commission on Ventilation used a duct of 8 square feet in its experiments and recommended this size. Professor Winslow has stated since that a duct of 4 square feet is ample. Mr. Wheeler declared that two ducts 18 inches square would be required for one classroom. Mr. Watt finds one duct 8 inches square



Sherman School, Fairfield, Connecticut, Where the Wheeler System of Window-Gravity Ventilation Was First Demonstrated.

Notice the open windows.

Windows Opened for Late Fall Ventilation in Sherman School, Fairfield, Connecticut.

Notice the glass window deflectors and radiators under windows.

satisfactory for the average classroom, the size of ducts in other rooms depending upon height. Mr. Cooper states that the size of the outlet duct is governed by the rules or laws which apply to the air movement. If a movement of 30 cubic feet of air, per minute per pupil is required, the size of the duct must be larger than otherwise would be necessary. Mr. Cooper states, however, that in gravity-exhaust ventilation without the use of fans, it is seldom that the air will move with greater velocity than 400 feet per minute.

It is generally agreed that ventilating ducts or flues should be proportioned in size to the room in which they are used. For sleeping rooms, Mr. Wheeler used a flue the size and shape of a chimney pipe; equipped it with a damper, or shutter, similar to that used for the old-time chimney pipe hole. Mr. Wheeler pronounced against flues that were too large. Also, he stated that a flue should have a long, vertical draw. He found that flues that are too short are not satisfactory. A warm flue operates best; consequently an inside wall is a better location for a flue than an outer wall. In a school building, the space between classrooms and corridors is an ideal location for a flue. But where chimney flues are available, these are satisfactory for the ventilation exhaust.

Mr. Wheeler recommended that flues be con-

structed of glazed sewer tile with hubs well set up with cement. Such flues, he stated, are safe against breakage, secure against leakage, and fireproof. The cost of construction of such flues is low. The only top necessary for a ventilating flue, according to Mr. Wheeler, is a cover to keep out the rain and snow, but so adjusted as not to interfere with the free outflow of air.

Ventilation of One-Room Schools

The principles of installation of modified window ventilation for one-room schools are the same as in larger buildings. There are a few common fallacies to be avoided. The belief that the stove or fireplace opening will act as sufficient exhaust for the removal of the foul air is carried over from the discredited carbon dioxide theory, which is the belief that carbon dioxide is the harmful element in expired air, and that, being heavier than the air, it must be removed at the floor line.

From our present knowledge of ventilation, it is evident that the lack of sufficient escape for the overheated air is the chief difficulty with the ventilation of the one-room school building. An outlet should be provided in the ceiling, leading through the attic of the school and out through the roof. The stack outside should be provided with a mushroom cover or cowl to keep out rain and snow; and,

inside, the opening should have a damper, or shutter, to open and close it.

Two-Way Duct an Aid

Another excellent means of providing ventilation is through the use of a two-way duct. This system was invented by Mr. Watt and has proved satisfactory for many kinds of rooms which cannot be adequately ventilated with windows and wall outlets. The two-way duct is literally an extension of the wall or ceiling outlet, through a duct which extends about two-thirds of the way across the room near the ceiling. The size of this duct is determined by the size of the room to be ventilated. For the average schoolroom it should be about 8 by 12 inches. Two such ducts, located one on the east side of the room and the other on the west side, should give good ventilation. The space between the intersecting ducts is not important. The ducts may be close together or several feet apart. Each of these ducts should be provided with a damper, or shutter operated by a chain or cord at the wall (see illustration).

When this two-way duct is in operation, it will be found that cool air will be blown in from outdoors at the same time that overheated air is removed from the room. Consequently, in the coldest weather, it will not be necessary to open windows. The ther-

mometer will indicate how much additional cold air must be admitted through the windows.

When top-window openings are too wide, cold air descends before it is diffused and a draft is created. It is better to open several windows each a quarter of an inch than one window four inches.

The rural school as well as other types of schools, should have a thermometer placed outside the building, as well as inside, to be observed in regulating the heating and the window openings. Thermometers may be protected against breakage by guards of wire, glass or wood.

In the one-room school, as in the larger building, the proper operation of the heating equipment is essential to good ventilation. It is desirable to keep the fire well checked after the room has become warmed sufficiently. Morning fires should be built early enough so that the room may be heated somewhat gradually rather than allowing the fire to get beyond control and thus to overheat the room.

Water kept steaming on a stove will provide humidity. If the heating is done by furnace, a humidifying attachment may be placed on the furnace. The belief that growing plants are a benefit to health is somewhat doubtful. Here again the carbon dioxide theory crops out since plants are well-known consumers of carbon dioxide. Plants give practically no help in increasing relative humidity.

Plants Thrive Where Children Do Not

One teacher, who was pale and sickly looking from long years spent in overheated rooms, used to boast of the healthful atmosphere of her schoolroom because her geraniums blossomed so freely. The nurse who visited the school had difficulty in making this teacher see the contrast between the hardy plants and the pale, anæmic looking children. Many varieties of plants and flowers thrive in a hot-house atmosphere and in high temperature, conditions which are seriously injurious to the health of children. But the teacher would not see that this was true. She refused to open her windows in cold weather.

"Do you think I would subject my pupils to that cold air?" she questioned indignantly, and added, "Besides, my plants would freeze."

But window-gravity-ventilated rooms are not always kept at a cool temperature. Sometimes the windows are not opened properly or are closed altogether and sometimes the coöperation of the janitor has not been secured to prevent overheating. Several schools visited in Connecticut were found to be neglectful of their opportunities for good ventilation in not fully using the window-gravity system which had been provided. Some helps to meet such situations have been suggested. Temperature charts seem the most successful.

Aids to Better Ventilation

The Pequot School at Southport, Connecticut, was using temperature charts when visited in late November, 1925. The temperature chart is fastened with a thumb tack to the wall near the thermometer. A pupil is appointed to read the thermometer when school opens each session and again two hours later. Readings are entered on the chart in the space provided for that date. The fact that the temperature recorded most frequently was 70 degrees F. led to a question. "A new janitor," was the explanation. Perhaps he was not told about temperature.

To help the janitor understand his responsibility in connection with ventilation, and the importance of the matter to the health of school children, the Metropolitan Life Insurance Company has issued a pamphlet on the subject written by Winslow and attractively printed. Through the generosity of the company this pamphlet is available for free distribution to schools everywhere. It should prove a great help to secure better school ventilation.

But most important of all is the plan to have some one person in the school act as supervisor of ventilation. In the new high school in Fairfield, Connecticut, the assistant principal has assumed this task. He holds conferences with teachers, and talks with the janitor on the subject of fresh air and its

importance, and how best to secure it. Many problems arise about which the teacher needs advice. Sometimes a room has an exposure which makes it difficult to heat. The teacher in such a room needs help to know how to manage the ventilation. She should have some one to whom she may appeal before the air in her room becomes uncomfortable. So, supervision of an efficient and helpful nature by one who is interested in the subject is a necessary part of the plan for effective school ventilation.

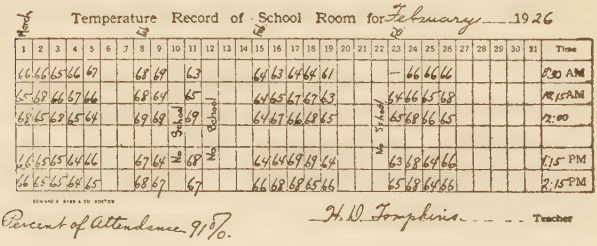
In a large organization with many schools under one superintendent, it would be desirable to have some one in the central organization thoroughly equipped to advise the various schools in regard to the operation of ventilation. This plan is followed in Evanston, Illinois.

It is believed that when architects and school officials devote the attention to window ventilation which they have given to mechanical systems, the results will be far more satisfactory and much money will be saved. Neither the Watt nor the Wheeler system claims to pronounce the last word in ventilation, but they point the way to satisfactory results through simple methods. No system of ventilation can be automatic. It will always be necessary for teachers to study the ventilation problems which their respective rooms present, and to make use of whatever helps they may have, to secure fresh air

for their pupils according to the accepted definition of that term.

Teach Ventilation to Pupils

The classroom offers an excellent opportunity for both teacher and pupils to work out the ventilation problems of the school. This should be taught as a



Temperature Record of School Room for February 1926

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Time
66	66	65	66	67			68	69		63				64	63	64	64	61				—	66	66	66						8:30 AM
65	68	66	67	66			68	64		65				64	65	67	67	63				64	66	65	68						10:15 AM
68	65	68	65	64			69	68		69				64	67	66	68	65				65	68	66	65						12:00
66	65	65	64	66			67	64		68				64	64	69	69	64				63	68	64	66						1:15 PM
66	65	65	64	65			68	67		67				66	68	68	65	66				65	68	64	66						2:15 PM

Percent of Attendance 91%

H. D. Tompkins — Teacher

TEMPERATURE CHART FROM PEQUOT SCHOOL, SOUTHPORT, CONNECTICUT. (UNDER FAIRFIELD, CONNECTICUT, SCHOOL SYSTEM.)

This is an excellent temperature record.

part of the lessons in physiology and hygiene. However, most textbooks have not treated the subject adequately. Some of the information about fresh air and ventilation is in need of revision.

The plan of the temperature chart is a good beginning, but pupils should be taught to adjust windows and to manage radiators intelligently, going by the thermometer, so that the proper room temperature may be maintained. This participation of pupils in room-ventilation problems fulfills two of

the newer conceptions in education; teaching by the project method and administration through the socialized classroom.

Where the health and comfort of pupils are concerned it is absurd for engineers to dictate that nothing must be done about room ventilation, except through the janitor of the building. Ventilation cannot be automatic; neither the janitor, nor the teacher, alone, can keep room air fresh and healthful. It requires the interested coöperation of all concerned.

In the kindergarten, the most unnecessary sins against fresh air are frequently committed, since the little people in these rooms are often up and moving around, and so could be happy in a lower temperature than most of the older school children, who must sit quietly at their desks. The teacher in the kindergarten should have some assistance from the principal or from children in the higher grades, to read the thermometer and keep the temperature charts. Such helpers could adjust windows and radiators two or three times during the session, if necessary.

It may well be considered one of the strongest points in favor of window-gravity ventilation that it brings both teachers and pupils into the plan. Children who have a continuous part in the project of proper schoolroom ventilation will receive a training which will go with them to their homes and later

into office and factory to enable them to promote good ventilation wherever they meet the need for it.

Window-Gravity Ventilation Gains Favor

Window-gravity ventilation is gaining headway slowly. Out of seven hundred new school buildings surveyed by McLure, forty-five had installed window-gravity ventilation by 1924.

Cities where it is used extensively are: Birmingham, Alabama; Kansas City, Kansas; Evanston, Illinois; and Fairfield, Connecticut. A survey made by the American Child Health Association reports that one half of the schools in some eighteen cities visited in New England were ventilated by the window-gravity method.

Some of these school buildings clearly demonstrate that window-gravity ventilation is not only feasible for smaller schools, but that it can be used successfully in the larger type of building.

Opinions from some school superintendents where window-gravity ventilation is in use were requested by McLure in the course of his study.

Superintendent C. B. Glenn, of Birmingham, Alabama, wrote: "We are sold to direct radiation with gravity ventilation."

Superintendent M. E. Pearson, of Kansas City, Kansas, reported that he has schools under his supervision ventilated by mechanical means, and schools

Escape for Overheated Air Shown in Ceiling of Library of an Evanston Illinois School

Watt system of window gravity ventilation.

with window-gravity ventilation, and that he is convinced that window ventilation is best.

Former Superintendent S. J. Slawson, of Bridgeport, writes:

> . . . Very much against my training and previously determined opinions, I am obliged to say after experience with the window ventilated buildings sponsored by Mr. Sam Wheeler of Bridgeport, that much of our theory, with reference to air currents in the process of ventilation carried on through expensively constructed and equipped heating plants, has resulted in a very great waste of money.[1]

The authors have corresponded with other superintendents. Superintendent William E. Smith, of Fairfield, Connecticut, states: "We have installed the Wheeler system of ventilation in all schools constructed since 1913. I think it the most satisfactory and economical system of ventilation I have seen."

Superintendent S. C. Thompson, of Stratford, Connecticut, says, "We have in Stratford all known types of ventilation, and considering the many factors involved I am convinced that the Wheeler system is our best."

Superintendent Fordyce T. Reynolds, of Gardner, Massachusetts, under date of December 20, 1925, states:

---

[1] J. R. McLure, *The Ventilation of School Buildings* (Teachers College, Columbia University, 1924), p. 95.

> We certainly are delighted with the Wheeler System. . . . I asked the nurse who has Coleman Street School (window-gravity ventilation) in her district, "Which is the healthiest school in your district?" "Coleman Street School," she replied. (No reference had been made to your letter). . . . The floors of this building have never been cold.

Superintendent J. R. Skiles, of Evanston, Illinois, one of the latest cities to adopt window-gravity ventilation by the Watt system for its schools, reports a lessened number of absences due to colds this year over last year when mechanical ventilation was in use. He reports a large conservation of fuel, in some buildings running about 30 per cent. In each room there is a thermometer on the teacher's desk. Pupils assist in air conditioning in most of the rooms and in charting the room temperatures, which average 68 degrees F., the highest temperature recorded being 72 degree F. in an occasional room.

Temperature Records Tell the Story

An analysis of the temperature records from two eight-room schools in Gardner, Massachusetts, for the month of February, 1925, was made by the authors. From February 2 to March 6, there were twenty school days. A total of 120 temperature records were made, an average of six each day. The first record is that made upon the arrival of the

Pupils Recording Thermometer Readings in Schoolroom at Evanston, Illinois.

Note thermometer on pupil's desk.

Pupil Adjusts Windows for Proper Schoolroom Ventilation during a Lesson in Fresh Air Conducted by a Pupil.

teacher, usually about 8:30 A.M.; the second is made at 9:00 A.M. when the session opens, and records are made hourly thereafter until dismissal. The afternoon records are made at 2:00 and 3:00 o'clock. The superintendent of schools explained that February is the coldest month in Gardner, the outside temperature often being as low as 10 to 20 degrees below zero. The two schools studied were Coleman Street, which has window-gravity ventilation, and School Street, which has plenum-fan or so-called "standard" mechanical ventilation.

Coleman Street showed an average temperature of 68 degrees F. for the period, while School Street School had an average of 72 degrees F.

The highest temperature recorded in Coleman Street School was that of Grade V, which had an average range of 69 to 73 degrees F. for the month, but in School Street School Grave IV had an average range of 74 to 80 degrees F. for the month.

Coleman Street exceeded a temperature of 75 degrees F. only 9 per cent of the time, whereas the School Street average percentage above 75 degrees F. was 31. Two rooms in School Street School had an average temperature of 80 and above, 20 and 25 per cent of the time respectively.

The chief offenses against a moderate temperature were committed largely during one week in all schools. It is assumed that the outside temperature

was particularly low at that period and that the schools, lacking provisions for control of humidity, sought higher and higher temperatures for comfort. One school went as high as 96 degrees F. on one occasion.

Preheating One Difficulty

However, the chief difficulty in both schools was with preheating. Rooms of the Coleman Street School averaged a temperature of 71.2 upon the arrival of the teachers and School Street averaged 73.4. Almost without exception, on days when the temperature was high upon opening the session, the teachers found it difficult to reduce it. However, Coleman Street showed an average record of 69 degrees F. upon closing, whereas School Street's average was 72 degrees F.

A recent observation[2] of temperatures in 278 schoolrooms in 31 cities gave the following classification:

Temperature, Degrees F.	Number of Classrooms	Per Cent
Below 66	16	6
66—70	110	40
71—75	104	37
Over 75	48	17

[2] *A Health Survey of 86 Cities* (American Child Health Association, 1925), p. 191.

It will be seen from this distribution that more than half of the rooms had a temperature above 70 degrees.

This study shows rather conclusively that the chief problem in ventilation lies with the janitors of schools and is manifested in overheating.

Summary

Open-air schools have benefited the health of children in attendance to such a marked extent that educators and health workers are eager to secure fresh air for all school children.

Mechanical systems, supported by outworn theories and state legislation, are slow to yield to more modern methods of ventilation.

William E. Watt of Chicago and the late Samuel H. Wheeler of Fairfield, Connecticut, worked out similar plans of modified window ventilation, each without a knowledge of the other's work.

Cool air has been discovered to be as beneficial to health as cold air. A temperature of 65 to 68 degrees F. has been accepted as the health zone.

Buildings of all sizes may use modified window ventilation successfully. Architects can design such ventilation plans.

No system of ventilation can be automatic. In the socialized classroom, teacher and pupils should share the responsibility for fresh air in the room.

Window-gravity ventilation in its simplicity and effectiveness offers an excellent opportunity to teach children the principles of good ventilation.

School superintendents approve window-gravity ventilation and feel that health will be promoted by its use and that much money will be saved for the taxpayers.

CHAPTER VII

WINDOW-GRAVITY VENTILATION IN FACTORIES

Architectural Difficulties

FACTORIES are no exception to the general rule that buildings are not constructed to permit modern scientific ventilation. Remodeling is usually necessary. With the older type of building it is not difficult to make an opening through the top of each room into the ceiling and walls and through the roof. But in case of the modern fireproof construction, difficulties often present themselves. In steel and concrete construction, there are usually no flues. The concrete floors with their steel girders make it difficult to cut through. But the Watt two-way duct overcomes these difficulties by carrying out foul air at one side of the building and bringing in fresh, unheated air from the other side without drafts; the direction of the wind governing the direction of flow. However, it would be simple to construct such buildings with a view to the installation of modern scientific ventilation.

Buildings of the mill construction type of brick and timber, where timbers are exposed, are the

easiest to ventilate. Vents can be cut through without difficulty, but proper precautions as to fire ordinances are necessary.

Saw-Tooth Construction

The saw-tooth type of construction presents even greater difficulties than the others mentioned. Such buildings are of one-story construction with serial peaks resembling the teeth of a saw. Skylights are located in each elevation. There are windows on the sides as well as in the roof.

Such buildings are cold in winter and warm in summer because of radiation from the extensive areas of glass.

William E. Watt was successful in bringing about a great improvement in the air conditions of such a factory in Rochester, New York. Windows at the sides of the building were lowered from the tops; some skylight windows were lowered by means of hinges. The heating was accomplished by blowers. Cold air was removed from the floors and recirculated through the fan chamber for this purpose. Humidity was introduced in the fan rooms. Fuel saving, quicker warming, and better air are results.

Heavy Fumes Removed Where Produced

The Eastman Kodak Company in Rochester, New York, needed relief in a department where benzol

THE TWO-WAY VENTILATION DUCT USED BY WATT IN FACTORY VENTILATION.

The fresh air is brought to the workers at the center of a large workroom removed from windows. (Courtesy Eastman Kodak Company.)

was used in manufacture. When proper outlets were made under benches to remove fumes, the gas was no longer a source of danger to workers. The usual ceiling outlets also were used. Fresh outdoor air brought in through windows and kept at a low temperature, added greatly to the comfort of employees in the department.

It is significant to notice how odors of different characters are dispelled in ventilation. Ordinary body odors and the usual annoying odors such as those arising from cooking are removed above through the ceiling ducts. In the case of a gas which is cold and heavier than air, it is necessary to convey this out of the room by the lower outlets. The higher outlets always are necessary in occupied rooms; but in some instances, in connection with manufacture, the lower ones must also be provided to carry off fumes.

Clothing Manufacturing Plant Benefited

Wilson Brothers, makers of men's furnishing goods in Chicago, were the first in this country to introduce modified window ventilation with gravity exhaust in a factory, in pressing departments, where heat and fumes produce headache and respiratory troubles. When fresh, moving air is introduced and ducts are opened in or near the ceiling; when the temperature is reduced from an average of 80 de-

grees to 70 degrees F. or less, the relief is great. One employee, whose physician had advised him to go West for his health, stayed on and improved in health while at his regular work. Conditions in the cafeteria and kitchen were improved by the introduction of ceiling ducts which carried off the odors and kept the air circulating pleasantly when windows were open slightly at the top.

Windowless Rooms Made Pleasant

Inside rooms can be supplied with air as fresh as those with outside exposure if proper ventilation is used. This can be done either by gravity, or by mechanical means. When gravity is used, a duct leads to the room from outdoors or from some room that has outside exposure. Another duct is used to dismiss the overheated air. These ducts will alternate in their action, depending upon the direction and pressure of the wind. In a large inside room both ducts usually extend about one-third of the way into the room as an aid to distribution. Both ducts have adjustable shutters which control the air flow.

The Medical Department of the Eastman Kodak Company, which contains several inside rooms, including restrooms and an x-ray department, is ventilated partly by mechanical means. Blowers deliver air to eight floors. The windows of outside rooms

Ventilation of an Interior Room Used for X-Ray Work.

It is ventilated by admission of fresh air through ducts and extraction of overheated air by duct, as shown in illustration. (Courtesy Eastman Kodak Company.)

are used by opening them at the top slightly. The volume of air delivered is much less than formerly and much of the time the blowers are not used at all. In summer, ice is used in one air chamber to dehumidify the air.

In one department where some difficulty was experienced with an engineer who liked overheated air, a self-registering thermometer was installed which continuously recorded the temperature automatically. This is one means of definitely centering responsibility for cool air in the person who is in charge of the ventilation.

Employees who have been used to high temperature cause the chief difficulty in introducing window-gravity ventilation. They imagine drafts and have strange fears of taking cold and becoming ill. So a part of the company's work in the installation of a low-temperature system of ventilation is in the education of employees, as well as in seeing to it that the installation is not producing drafts. This involves intelligent supervision and effective teaching.

The maintenance of the temperature at the degree desired requires some one to look after windows and radiators and to read the thermometer regularly. One plant of the Eastman Kodak Company has authorized the foreman of each department to appoint a man to look after the ventilation. Then a representative from the central office, a man with

recognized authority, visits these department representatives several times a week and advises them with reference to the problems affecting their individual departments.

The manager in charge of the ventilation of the plant says:

> We have emphasized the avoidance of overheating (using too much steam) and the subsequent chilling of the room by throwing windows wide open. We have asked to have radiator valves shut off *before* the room is overheated and a little ventilation (opening *upper* window sash) at all times.
>
> Splendid results have been obtained by this method and will be continued as long as interest in the subject is constantly kept alive by frequent visits and check-ups on the departmental ventilation men.
>
> Instruction has been given the night firemen and the watchmen regarding the part they are expected to play in producing, during the night, right air conditions, so that work may be started at 7:45 A.M. under favorable conditions.

The instructions well illustrate the point emphasized by the New York State Commission on Ventilation that constant vigilance is the price of good ventilation.

Results of Window-Gravity Ventilation

The Hawk-Eye Plant of the Eastman Kodak Company, Rochester, New York, has recorded the

following results from experience with window-gravity ventilation:

SICKNESS AND SICK BENEFITS PAID

Period	Type of Ventilation	Cases Ill	Hours Lost	Benefits Paid	Average Number of Employees
One year, April to April 1923-1924	Mechanical	30	3608	$1,201.00	516
One year, April to April 1924-1925	Window Gravity	19	1706	$ 602.19	496

Through the new system of ventilation and cooler temperatures in workrooms, sickness was cut down one-third over the same period the year previous. Sick benefits paid by the Employees Sick Benefit Association amounted to half of that paid the previous year. Four hundred ninety-six employees did the work of five hundred sixteen the year previous, thus increasing the rate of output 4 per cent.

A study of coal consumption during the heating season was made with the results shown in the following table:

Coal Consumption

Period	Type of Ventilation	Mean Temperature	Tons of Coal Burned
October, 1923, to March, 1924	Mechanical	34° F.	1,025
October, 1924, to March, 1925	Window Gravity	35° F.	953
			Difference ..72

The installation of window-gravity ventilation paid for itself in one year in this plant.

Hill relates:

H. M. Vernon has estimated that in a tinplate factory a more efficient ventilation increases the output by 12 per cent over that of the badly ventilated factory.

I believe that by really adequate ventilation a much greater increase in output would result.

The heating of the air is a method which inevitably depresses health and spreads respiratory disease, and yet this is a method now largely employed.

The use of small sources of radiant heat, one supplied for each worker and under his or her individual control is a problem which requires to be studied. The Japanese have done their fine work with nothing but little charcoal stoves at which to warm their fingers.[1]

[1] Leonard E. Hill, *Atmospheric Conditions and Efficiency* (Longmans, Green & Co., 1923), p. 121.

When Fans Are Needed

In instances where the process of manufacture produces unusual heat, dusts or fumes, fan exhaust may be required. Fans also will be needed to aid in cooling the air of the workrooms.

Steel plants have brought about greater comfort to workers by forcing cool air through small openings in the floor.

It is recognized that industry presents the most complicated and varied of all problems in the ventilation field.

England Studies Factory Ventilation

In England, the Industrial Fatigue Research Board, financed by the government, conducts continuous research in ventilation problems in industry as a part of its program of activities for the benefit of the health of industrial workers.

D. R. Wilson, the secretary of the Board, when seen in his office in London by one of the authors, related some of the experiences which the investigators had encountered in the textile and tinplate industries. In operations where the processes of manufacture require a high temperature, the health of workers has been benefited and their comfort greatly increased by the introduction of fans. It has been found that air in motion, even if the tem-

perature must be high, is a means of lessening industrial fatigue.

Charles S. Myers,[2] director of the National Institute of Industrial Psychology, London, stated recently in a personal interview that the introduction of proper ventilation had improved the health and increased the output of workers in the textile and tinplate industries in England. He further said that investigators, who were surveying the conditions of work of electric workers employed on batteries, found them subjected to both heat and fumes. These investigators recommended that the plenum-fan system be reversed, as the hot air in the plant needed to be removed from the top of the rooms. The plenum system introduces warmed air at a higher point and dismisses supposedly "foul" air at the floor line.

H. M. Vernon and his assistants, working under the direction of the Industrial Fatigue Research Board, London, have recently published a report to show something of the nature of their work and its results.[3] A significant contribution to the study of ventilation may be the portable hot-wire anemometer which Vernon has devised. This instrument

---

[2] Member, Industrial Fatigue Research Board.

[3] H. M. Vernon, "Methods of Investigating Ventilation and Its Effects," Medical Research Council, Great Britain, 1926, Spec. Rep. Series No. 100.

Window Set Open for Winter Ventilation in Office; Outlet is through Slightly Opened Transom.

Double-hung vertically sliding window here shown is best for ventilation. Note the window shade is set down slightly from the top to allow a passage of air over it and to prevent it from rattling in the wind. (Courtesy Eastman Kodak Company.)

is said to be most accurate in its ability to measure the oscillation or movement of air in a room. As contrasted with the kata-thermometer, it is said to be more reliable, in one way, since it will measure descending currents of air satisfactorily. The principle of the hot-wire anemometer is based on the discovery of Ser (1888) that the convection loss from a heated wire is proportional to the square root of the velocity of the air current moving against it.

Observation of the freshness of air under variable atmospheric conditions resulted in the discovery that a temperature of 68 degrees F. with an air movement of 41 feet per minute was the most satisfactory for factory workers in summer, while a temperature of 61.5 degrees F. with a velocity of 28 feet per minute was the most comfortable for winter. Outside temperatures in summer and in winter, of course, influenced these decisions.

Vernon states that the effect of the clothing on the cooling rate of the body is considerable. Thus it is calculated that the unclothed body of the subject of experiment would remain in temperature equilibrium at an air temperature of 81 to 83 while the warmly clad body would remain in equilibrium at an air temperature of 59 to 60. Hence, in order to induce an actual cooling of the overheated body of a man engaged in hot and heavy work, it is of most importance to reduce the temperature and next

in importance to reduce the clothing, while increase of air velocity has but little effect.

Principles of Window-Gravity Ventilation Upheld

The principles of modified window ventilation are upheld throughout by the English investigators as a result of their studies. When it is not practicable to use windows, however, the admission of fresh outdoor air at an 8-foot level through artificial impulsion is advised. It is specified that the extraction of air is to be made at the ceiling or roof. Floor heating promises lower comfort temperature.[4]

Some studies on the effect of humidity upon output have been made by Vernon. The effect of humidity on output is small but is definite. Output is greatest around 50 per cent relative humidity and falls off as 55 to 60 per cent is approached."[5]

Temperature is a more important consideration in industry than elsewhere, since so many processes of manufacture are affected by it. Consequently the problem of factory ventilation offers more difficulties than usually are found in other enclosed places.

No hard and fast rule can be laid down as to the most suitable temperature for workshops and factories

[4] H. M. Vernon and others, "A Physiological Study of the Ventilation and Heating in Certain Factories," Industrial Fatigue Research Board, 1926, p. 21.

[5] H. M. Vernon, "Industrial Fatigue and Efficiency," Industrial Fatigue Research Board, p. 243.

. . . the accidents at a fuse factory reached their minimum at a temperature of 65 to 69 degrees F. but this is distinctly too high for the maximum efficiency of operatives engaged in fairly active work. It may suit their comfort but it is not sufficiently stimulating. Undoubtedly the temperature ought to be varied in different shops, according to the character of the work done and one American firm worked out the following scale of temperatures which were placarded throughout the works, and were maintained by a temperature boss who was chosen in each shop to keep an eye on the thermometer:[6]

Suggested Temperature Standards

Offices, drafting rooms and rooms where workmen are seated at their tasks, 67 to 69 degrees F.; rooms where men are moderately active and able to move about, 65 to 67 degrees F.; foundries, smith shops and carpenter shops where active work is the rule, 55 to 65 degrees F.; storage rooms where men are not regularly employed, 40 to 50 degrees F. These temperatures are somewhat high, unless there are fairly good currents of moving air.[7]

Contrast, with what has been said in the foregoing chapters in regard to temperature and health, the following temperatures which have been observed in various work places:

---

[6] *Ibid.*, p. 238.

[7] Kober and Hayhurst, *Industrial Health* (Blakiston's Sons & Co., 1924), p. 758.

Kind of Operation	*Degrees F.*
Starching and ironing in laundries	95
Tending electric furnaces	100–120
Vulcanizing and japanning	90
Evaporating rooms of sugar refinery	110–115
Copper reduction	100
Manufacture of oxygen	100–120
Bakeries	90

These figures give an idea of the ventilation problems which confront industry. Kober and Hayhurst have listed thirteen industrial hazards, four of which have to do with ventilation.

Two statutes recorded in the Factory Laws of 1924, compiled by the American Association of Labor Legislation, mention window ventilation. Arizona requires every room in a laundry to have at least two windows connecting with the external air and so arranged as to provide a cross current of air. Delaware requires cigar factories to "open windows 30 minutes before working hours and 30 minutes after working hours," and that "the work rooms shall be so ventilated that the air shall not become impure and injurious to the health of the persons employed therein."

Industrial Physician and Ventilation

Emphasis in factory ventilation, as in school ventilation, should be placed upon adequate inspection and supervision. This fact has been recognized by

W. Irving Clark[8] who describes the special duties of the industrial physician in industrial ventilation as follows:

1. Routine inspection to detect poor ventilation.
2. Conference with the engineering department on questions of ventilation, especially the installation of new ventilation when this is contemplated, or repair of the old system.
3. Routine temperature and humidity readings in special departments and coöperation with the engineering department in reducing this hazard.
4. Inspection of hoods, suction apparatus, etc., for the removal of fumes or dust, when these are in operation.
5. Special attention to the ventilation, and the elimination of offensive odors, in toilets and locker rooms.

Among the industrial physicians who have taken an especial interest in the newer scientific knowledge of ventilation and who have applied this to benefit the health of a large number of employees, is W. A. Sawyer, chief of the medical department of the Eastman Kodak Company, Rochester, New York.

Summary

Factory buildings, like most other modern structures, are often constructed without regard to scientific ventilation.

---

[8] W. Irving Clark, Jr., *Health Service in Industry* (The Macmillan Co., 1922), p. 114.

The saw-tooth type of construction is the most difficult to ventilate.

Fumes heavier than air should be removed where produced, but odors such as may arise from cooking must be dispelled at the ceiling.

Inside rooms can be ventilated with fresh air by use of ducts leading to them from the outside, or from a room which has a good air supply.

One factory used a self-registering thermometer which automatically recorded the hourly temperature, as a check on the engineer who had the habit of overheating the building.

Employees often need to be educated to enjoy lower temperatures.

Night firemen and watchmen play an important part in ventilation; they are responsible for the air conditions in the plant when the employees arrive in the morning.

Hours lost by employees on account of illness, and sick benefits paid to employees were reduced one half and fuel consumption was cut down as well, in the Hawk-Eye Plant of the Eastman Kodak Company, through the introduction of modified window ventilation.

Health was improved and output increased in tinplate and textile industries in England after good ventilation was introduced.

Industrial Fatigue Research Board of England finds that air in motion, even if the process of manufacture requires a high temperature, lessens fatigue.

H. M. Vernon has a new instrument called the "hot-wire anemometer" for measuring the movement of air in a room.

English investigators uphold principles of modified window ventilation.

Schedule of room temperature has been worked out for various operations in industry, according to amount of physical exertion required of employees.

One-third of all industrial hazards involve problems in ventilation.

Industrial physician has distinct part in industrial ventilation.

CHAPTER VIII

WINDOW-GRAVITY VENTILATION PRACTICABLE FOR GENERAL USE

OFFICE buildings are notably lacking in proper ventilation. When windows are relied upon solely for fresh air there is usually a disagreement about the opening of them. Those seated nearest open windows are too cold and those farthest away are too warm. Overheating is almost universal. In some offices it is impossible to turn off, or to modulate, the heat.

Window-gravity ventilation operates chiefly to reduce high temperatures and to remove the general air stagnancy which exists. The outlet near the ceiling, with windows opened only slightly in the coldest weather, gives ample air movement without any sensation of a draft. If windows are opened at the bottom, deflectors should be used. Radiation is too ample, usually, so that heat should be turned off after the room becomes sufficiently warm in the morning. A small amount of hot steam humidity

applied to the air by means of a scientific humidifier adds comfort to the large office.

When window-gravity ventilation is introduced into a large office, it is desirable to explain its purpose to the workers in advance. Printed rules about fresh air and the operation of window-gravity ventilation should be distributed. Some one person in each department should be assigned to look after the control of the ventilation.

Experience has shown that in a group, even where the majority hail the better air conditions with delight, from 2 to 5 per cent of members of the group will oppose a lowered temperature and will take occasion to complain of the slightest air movement—calling it a draft. They will even go so far as to attribute ailments of long standing to the new air conditions. Often these dissatisfied ones become strong supporters of the fresh-air rooms when they notice the improvement to their health resulting from them. It is well to remember that in any group there will be some opposition to any change. This is a well-known psychological reaction and has very little to do with the innovations in themselves.

New Ventilation in Office Building

The Edison Building in Chicago is one of the most recent to employ window-gravity ventilation. In cold weather air is admitted through window tops

or from ducts at the ceiling. The upward travel of air is regulated so that it is drawn out through the transoms. Thermostats are set to prevent overheating. One person in each department is given control of the ventilation. It is made clear to these persons that the conditioning of the air is of first importance among their duties. No rush of other work is to interfere with it. These persons in charge of the ventilation are impressed with the fact that upon them, largely, depends the success of the day's work of all the force, their comfort, health and good cheer. All these important things hinge to a considerable degree upon fresh air.

Double-Hung Windows Best for Ventilation

Double-hung, vertically sliding windows are the best adapted for use in window-gravity ventilation. Where pivot windows are encountered the problem is slightly complicated. Sometimes it is necessary to cut an opening in the glass over which a slide can be drawn. Windows which simultaneously lower from the top when raised from the bottom, even though provided with deflectors, must have this double feature eliminated in order to give satisfaction in a small office. Any kind of window may be satisfactory in mild weather; but in the winter season, the type of the window is of utmost importance in ventilation.

Stores Have Problems to Secure Fresh Air

Department stores and other stores where many people congregate, and where outdoor wraps are not removed, have many difficult problems in ventilation. Some of these stores are heating their vestibules in winter, but keeping a low temperature in their various departments. This is wise for the reason that the uncomfortable customer, whose olfactory nerves record an unpleasant sensation upon entrance to the store, is not likely to remain long enough to make many purchases. Employees, forced to work in overheated, unpleasant air, haven't the energy to make goods attractive to customers. Fresh air as an important aid to trade has been overlooked too frequently.

An interesting illustration of improvement in air conditions is observed in the five and ten cent stores. In the early part of their history they were not equipped to take care of large crowds of people, some of whom were neglectful of cleanliness, and yet keep the air of their stores pleasant. The hot, odorous condition of these places made them centers of much criticism. "It's as much as your life is worth to go in there," or "I'd rather pay twice as much, than to get into that bad air," were comments frequently heard. To-day practically all of these stores are keeping the temperature down, using window

ventilation quite largely, and providing exhaust ducts for the extraction of the overheated air. Practically the same experience has been repeated in the case of motion-picture theaters. Especially was this true of the smaller houses, although all were violators of the best ventilation practice at one time. To-day, public opinion has forced many places to maintain a moderate temperature with air movement. In every instance, it is the public at large which is responsible for improved health conditions. Therefore, no progress can be expected without an enlightened public opinion.

Air More Important Than Plate Glass

Plate-glass windows are sometimes installed with no transoms above them. This often leaves a store with no possibility of fresh air from the one side where it might be admitted. Lyon and Healy, in Chicago, solved this problem by sacrificing their plate-glass window to fresh air. They had a mezzanine floor where a number of clerks were at work. This floor was unbearably hot most of the time. No fresh air was possible for it. The only windows were those at the front of the store, and these were of plate glass. It was necessary to cut an opening straight across the top of this glass, allowing it to open as a transom. Outlet ducts were introduced in the ceiling to carry off the overheated air. This

mezzanine floor, which had been responsible for so much illness and even for resignations among the clerks, became a pleasant and agreeable workshop.

The same store had another ventilation problem in its basement. Here it maintains extensive stock rooms and a shipping department. The place was stuffy and most uncomfortable. To remedy this condition fresh air was admitted through a duct cut through an outside wall. The hot air was removed at the ceiling and the basement became as pleasant as any other part of the store.

Banks Have Ventilation Problems

Banks, as they often have wide, open spaces for customers, do not seem to present problems in ventilation. But back of the cages the clerks often suffer. Officials, too, sometimes complain. The bank guard in one bank had taken his position after some years in the open air. He wore a heavy uniform and when the day was over he invariably went home with a headache. Another bank had many clerks at work on a mezzanine floor. All of these workers were made more comfortable when window-gravity ventilation was installed and properly operated.

Some banks, like schools, theaters and other indoor places, still rely upon mechanical systems to deliver fresh air. Not many bank officials, it is

hoped, are so afraid of fresh air as one bank manager is reported to be. In this particular bank building, a sum of $250,000 was expended for research and for equipment of ventilation. When outdoor air was mentioned to this manager as more desirable than that which the mechanical system supplied, he registered horror. "Why," he said, "outdoor air isn't fit to breathe. It is full of disease germs and other dangerous matter." He named "carbonic acid" and "sulphuric acid," which he said needed to be washed out of the air before it was fit to breathe. Very possibly some advocate of mechanical ventilation in all good faith had given this perhaps otherwise intelligent man, a great deal of misinformation.

Theaters Can Be Well Ventilated

The problem of ventilation of the large auditorium has always been the most difficult. Theaters especially have had complicated problems to meet. Usually the air is fairly fresh when the curtain is raised so that fresh air may come into the house from the wings off of the stage; but this freshness sometimes fails to reach those in the rear of the house. Overheating is the rule, and air movement without draft is most difficult to achieve.

It was the opinion of the New York State Commission on Ventilation that natural, or window-gravity ventilation alone, could not be used suc-

cessfully in large auditoriums, although no experiments were conducted which provided scientific support for such a conclusion.

William E. Watt has introduced natural upward ventilation in the Regent Theater in Rochester. After more than a year's experience with this method, during which the theater has had two different managers, both the retiring and the incoming managers are reported to heartily endorse it. The new manager was formerly connected with a very large theater where mechanical ventilation was of the latest and most costly design. It is said that he is convinced that gravity ventilation is the best for theaters.

Churches have usually been very difficult to ventilate. Several churches are reported to have found window-gravity ventilation successful. Among them is the new Baptist Temple in Rochester, New York, ventilated by Watt.

Hospitals and dispensaries should be particularly careful to provide fresh, invigorating air to patients. Yet how seldom does one enter a hospital or a dispensary where the air is pleasant and free from odor. A few physicians have appreciated the value of fresh air in the cure of disease, but one has only to recall the character of the air in most physicians' offices to realize that the appreciation of the everyday use of ventilation, as well as of the therapeutic

value of fresh air is acquired slowly. This has apparently not been a part of the physician's training, even in the best medical schools.

Homes Made Attractive by Pleasant Air

No matter what else a home may possess in the way of attraction nothing can compensate for the lack of pleasant-feeling, sweet-smelling air. Visiting nurses who visit the homes of the sick have a constant struggle to get the family to use fresh air as a preventive and curative measure. Often this is because the nurses themselves do not understand how to obtain the admission of fresh air without drafts and discomfort. One district supervising nurse had her nurses specially instructed in the methods of window-gravity ventilation.

The late Samuel H. Wheeler had his large residence at Fairfield, Connecticut, ventilated throughout by the window-gravity system. Windows are set open such a small crack that one would not observe that they are open at all in cold weather. But each ceiling vent is kept fully or partly open continuously. These ducts lead directly through to the roof and there are protected with caps of metal, so that rain and snow will not be admitted into the house through the openings. Shutters also are provided to close the openings in case of severe storm. Bedrooms and bathrooms throughout the

house are provided with these ducts, as well as the living rooms.

Wheeler Gets Quick Action

It is related that one bedroom had been overlooked until a time when a large house party was expected. Mr. Wheeler happened to observe that no ceiling duct had been provided for the room and that two beds had been made up there.

"Why, this will never do," said he, "we must have a duct cut in this ceiling before the guests arrive." A carpenter was sent for and the duct was cut, about 8 inches square, in the ceiling opposite the windows. All was completed and in satisfactory working order when the guests arrived that night.

This incident gives an idea of the simplicity of the window-gravity system and how readily it may be introduced into practically any home.

Mr. Wheeler is reported to have been especially thoughtful for the health and comfort of those employed in the house. Their rooms also are ventilated. In the instance of one employee, a seamstress, the introduction of a duct in the sewing room, about the middle of the ceiling, added so much to the healthfulness of the air of the room that the seamstress, who had been ailing, experienced a notable improvement in health.

The day is past when fresh-air cranks advise, "Throw the window open wide," and "All the fresh air you can get is just enough fresh air," and similar slogans. We know that in most climates of the temperate zone between November and March, to throw a window wide open will result in chilling a room so that it will not be comfortable for the occupants. With window-gravity ventilation, it is possible to have fresh air with comfort in the same degree that it is experienced out of doors on a mild summer day. That is the kind of fresh air which every one will accept, and it is all that is necessary to keep the normal body in health.

Homes which cannot secure the ceiling ducts can keep their windows open very slightly at the top. In cold weather the opening need only be just sufficient to make visible the merest crack of sky or light. It is important, however, that the air be admitted at as many points as possible.

For those who are afraid of thefts from open windows, there is a simple device to attach to the open window, which secures it from a further opening.

Window deflectors may be used for the sleeping rooms where a cooler temperature, and consequently wider window openings, are desired. It is possible to secure glass deflectors 15 inches high, allowing for a protection from a considerable opening.

Ventilation of a Sleeping Room

"Keep bedroom windows open" is a health slogan which has done much for health in every community. A wealthy philanthropist whose special interest was the Tuberculosis Association of a certain small city took pride in noticing how the windows in the sleeping rooms of that town gradually opened between 1908 when he began his crusade and a period some six or eight years later.

"I used to look at the windows of the silent houses when I came home from a trip early in the morning," said he. "Not a window would I see open. Now almost every sleeping-room window is open."

The bed should be placed where the sleeper will get the benefit of the open window. Observe the construction of most sleeping rooms and see how carefully the architect has planned that the bed shall be in some sheltered corner, as remote as possible from a window.

"I should like to have my bed by the window," some good housewife complains, "but you see how awkward it will make my room appear. There is no place for the bed but in this corner."

"Oh, I need that light space between the windows for my dresser," the fastidious flapper housewife proclaims. "I couldn't see to powder my nose if I placed the dresser in that dark corner!"

When there is a real, worthwhile objection to locating the bed permanently in a favorable position for fresh air at night, it may be suggested that furniture is movable, and in the interest of health and a pleasanter sleep, the bed might be moved about, placing it by the window at night and back in the corner during the day.

So we observe that most houses, particularly in respect to their sleeping rooms, have not been planned and constructed for fresh air, any more than have most other buildings.

Benjamin Franklin was one of the earliest exponents in this country of fresh air in the sleeping room. In the "Art of Procuring Pleasant Dreams," he says, "Another means of preserving health is to have a constant supply of fresh air in your bedchamber." He advises abolishing the curtains which enclosed the beds of most sleepers in his day. He traces unpleasant dreams to lack of fresh air, too much bed covering, and hearty eating before retiring.

Franklin recalls the fact that Methuselah preserved his health, presumably by outdoor sleeping; for when he had lived five hundred years it is recorded that an angel said unto him: "Arise, Methuselah, and build thee an house, for thou shalt live yet five hundred years longer." But Methuselah answered, "If I am to live but five hundred years

longer, it is not worth while to build me an house; I will sleep in the air as I have been used to do."

Franklin was one of the early observers to appreciate the fact that fresh air is chiefly a benefit to the skin. It is doubtful whether those who have been used to high indoor temperatures can sleep in the open with much benefit. Their tendency is to so overload themselves with bedding that the good effects of the air are considerably lessened. In building and planning the heating of our American homes we have valued comfort more than health.

Summary

Careful explanation of window-gravity ventilation is desirable to win coöperation of employees before it is installed in an office.

The ordinary double-hung, vertically sliding window is the best for ventilation.

Some stores have appreciated the advantage of fresh air to trade and have improved the ventilation even at the sacrifice of plate glass in show windows.

Mezzanine floors can be made pleasant for workers by introduction of window-gravity ventilation.

The large motion-picture theater finds modified window ventilation satisfactory.

Homes are much better ventilated when ceiling outlets are used, especially in bedrooms.

Kitchen odors can be carried off without penetrating other rooms when ceiling outlets are provided.

CHAPTER IX

VENTILATION COSTS

McLure[1] has shown that the cost of mechanical ventilation in a representative school building may be as much as 53.5 per cent of the total cost of the heating and ventilation contract. The Jefferson Intermediate School of Detroit, Michigan, expended $56,779.62 for its ventilation system.

It is customary to combine the costs of heating and ventilation. McLure found it necessary to secure data from the engineering firm responsible for the installation, in order to arrive at his conclusions. He segregated the items involved in ventilation alone and then those involved in heating. Then he considered the items common to both.

Other schools investigated by McLure showed expenditures for ventilation varying from 43.3 to 47.6 per cent of the entire cost of heating and ventilation. In the average school where mechanical ventilation is used, the cost of the ventilation may be estimated as between 40 and 50 per cent of the entire contract cost for heating and ventilation.

---

[1] J. R. McLure, *The Ventilation of School Buildings* (Columbia University Press, 1924), p. 88.

Costs of Ventilation Systems Compared

McLure [2] points out that for purposes of comparison between various systems of ventilation it is better to consider the cost of heating and ventilating per cubic foot of the building. He suggests that a more accurate method still would be to consider the cost of cubical contents of the building actually heated and ventilated. Data on the cubical contents actually heated and ventilated were not available.

McLure [3] has published figures comparing the costs of various systems of heating and ventilation. His table follows:

COSTS OF INSTALLATION OF VARIOUS SYSTEMS OF HEATING AND VENTILATION

Kinds of Systems	*Average per Cubic Foot of Building Contents*
Unit System	4.72 cents
Split System (individual ducts)	4.42 "
Split System (trunk ducts)	4.09 "
Direct-Indirect System	3.60 "
All Blast Steam System	3.33 "
Split System (exhaust flues and fans only)	3.25 "
Furnace—Blast System	2.98 "
Direct Heating and Window-Gravity Ventilation * (Wheeler System)	2.87 "
Direct Heating and Window-Window Ventilation	2.43 "

* Recommended by the New York State Commission on Ventilation as being the most generally promising method of ventilation for schools.

[2] *Ibid.*, p. 104.

[3] *Ibid.*, pp. 105, 106, 107.

The foregoing table needs explanation since it would appear that while window-gravity ventilation is quoted at a much lower figure than the mechanical systems, yet it seems comparatively high when it is considered that no mechanical equipment is used. It may be assumed that the cost of heating equipment in all systems is practically the same. McLure has explained that in the mechanical systems the cost of ventilation equipment is one half that of the entire contract. Assuming then that heating equipment will cost approximately two cents per cubic foot of building contents, it will be seen that whereas the ventilation equipment cost is two cents per cubic foot in mechanical systems; in window-gravity ventilation the cost is less than one cent per cubic foot of building contents.

Also, McLure's figures were based upon the Wheeler system of window-gravity ventilation which calls for window deflectors. The Watt system is even less costly since it does not use the deflectors and requires that only half as much radiation be provided as usually is called for. Watt installed the ventilation equipment for the Evanston schools at an average of $59 a room, which would amount to $1,180 for the average building of twenty rooms, as contrasted with the cost of $50,000 for mechanical equipment.

The system of ventilation which introduces fresh

air by means of ducts and a blower, instead of using windows, costs approximately $650 a room. The ventilation apparatus with this system, for the fourteen-room school at West Haven, Connecticut, cost $9,000. The operation of this system, of course, is more costly than modified-window ventilation, although no definite figure has been obtained for the cost of operation.

A Saving of Fuel in Window-Gravity System

A large saving in fuel with the window-gravity system of ventilation is possible under favorable conditions. Superintendent J. R. Skiles of the Evanston public schools writes:

> A large conservation in fuel is evident in some buildings, running about thirty per cent. Comparisons of burnings in different years will always be affected by outdoor temperature and wind forces, both being variable. Although the present winter (1926) was more difficult than last, we have paid $9,078.18 for coal to date (April 30), while last year we paid $15,620.00 with fewer rooms to heat than we have this year.

Before his death Mr. Wheeler of Fairfield obtained the following figures to support his belief that lower temperatures and avoidance of overheating should effect a fuel saving:

> The Sherman School, Fairfield, Connecticut, with direct steam radiation and natural upward ventilation,

used in one season 82½ tons of coal. There are twelve classrooms and two playrooms; that is, less than seven tons of coal per classroom was needed during the season.

At other modern schools in neighboring places (all from which information could conveniently be had) with 415 rooms, with indirect heating, and downward ventilation, 4208 tons of coal were used during the same season, more than ten tons per class room.[4]

Overheating the Greatest Cause of Waste

But the greatest waste in heating does not come through the use of mechanical systems of ventilation but through the American custom of overheating.

When room temperature mounts, the relative humidity is lowered. Dry air is not a good conductor of heat; so, the lower the relative humidity, the more necessary it is to have a high, so-called comfort temperature.

Hubbard has explained the extravagance in overheating as follows:

The percentage of heat loss varies with the comparative temperature inside and outside of the building, and is modified by wind pressure, window exposure, by leakage and by porosity of structure. As we raise the inside temperature from 60 to 70 degrees F. there is a higher percentage of loss than in heating from

[4] Samuel H. Wheeler, "Natural Upward Ventilation" (pamphlet, 1920), p. 5.

50 up to 60 degrees F. It will take almost as much coal to raise the temperature from 60 to 70 degrees F. as from 20 up to 60 degrees F. This comparison implies more or less imperfection in heating apparatus and faulty house construction. There are many factors involved not possible to estimate theoretically, and the only fact to be impressed here is that a high comfort temperature should be classed as an extravagant luxury. The practical point is that a reduction of even five degrees means less extravagance. A temperature of 70 with a very low humidity may be actually chilly; so we stoke up the dry-kiln heater and roll along in the vicious circle with the comfort goal receding. . . .

Americans are becoming progressively more sensitive to temperature and humidity. The popular demand seems to be for higher radiation capacity, in the home, in hotels and in public conveyances. What a shock to the heating trade if we accepted a 65 degree standard![5]

Mechanical Equipment Largely Idle

McLure has shown, through his study, that systems of mechanical ventilation are unsatisfactory, costly, and are not operated, as a rule, outside of the heating season. He shows that millions of dollars of idle ventilation equipment are to be found in the schools of New York City alone; and that this condition is duplicated, only on a correspond-

[5] Thomas Hubbard, "Hot Air and Comfort," *The Journal of the American Medical Association* (October 3, 1925), Vol. 85, No. 4, p. 1022.

ingly smaller scale, in every large city in the United States.

Window-gravity ventilation costs, in equipment and installation, 35 to 75 per cent less than split plenum-fan ventilation with individual ducts, or so-called "standard" ventilation. All unbiased evidence indicates that window-gravity is the coming system of ventilation for schools as well as for many other types of buildings.

In view of the increased cost of education which confronts every community, the saving in equipment and installation cost of the window-gravity ventilation adds very telling and material strength to the fundamental health argument, and should persuade all school architects and other school officials to give the non-mechanical systems of ventilation careful and impartial consideration.

The waste in ventilation begins with the installation of a mechanical system, continues through the overheating of rooms and has no end of by-product wastes on every hand. The waste of materials, fuel, labor and money, that might be put to better use, is insignificant compared to the waste in efficiency, the lost time due to sickness, the gradual breaking down of health of all who must live and work in overheated rooms. Who can even approach an estimate of the cost of inefficient ventilation? Its cost is beyond computation.

Summary

Representative city schools often spend, each, $50,000 for ventilation equipment.

Comparative costs of ventilation systems show window-gravity ventilation to be less expensive than mechanical ventilation, both to install and to operate.

Overheating is one great cause of waste in mechanical ventilation.

Waste of useless equipment, fuel and labor are not to be compared with loss of efficiency and injury to health caused by high-temperature rooms.

CHAPTER X

DEVICES TO AID VENTILATION

Types of Windows Compared

WINDOWS are the most important factor in ventilation, hence the type of window needs to be carefully considered. One sees many new kinds of windows in use to-day, but experience in modified window ventilation indicates that the ordinary double-hung, vertically sliding window is the best.

For some years health workers have recommended that windows be opened top and bottom, the theory being that the stale air would pass out at the top and the fresh air would enter at the bottom. Some of the window manufacturers have reflected this teaching in the types of windows constructed. Thus a certain type of window is seen in some office buildings which opens simultaneously from the top and bottom. Another type adds two other improvements which health workers have advocated, the glass deflector at the bottom and the cotton screen at the top. Until such a window is actually put in practice, it seems a useful device. In actual use in winter, in the small office, it permits a draft.

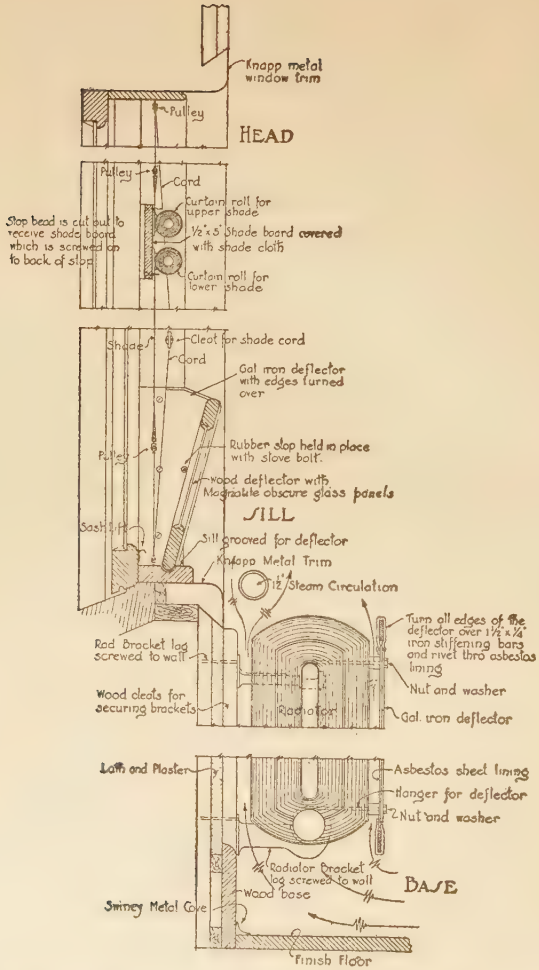
How to Open Windows

The newer teaching in ventilation advises that a window be opened slightly at the top, or raised from the bottom where a deflector is installed for protection against drafts.

In cold weather the crack at the top of the window, so slight that it cannot be noticed except at the joining of the upper and lower sash, may be found ample to provide fresh air. On the other hand, rooms are made uncomfortable, except during sleeping hours, by the simultaneous opening of a window from top and bottom. In some cases the current of air short-circuits from the bottom to the top, perhaps without discomfort, but in other cases cold air may enter at both top and bottom openings and make a room chilly.

Pivot windows cannot be opened in cold weather without a draft, usually because the opening is, of necessity, too large. Hence pivot windows are practically useless for ventilation in cold weather.

French windows which open like doors cannot be used for ventilation in cold weather. Some portions of such windows need to be cut out and fitted with supplementary windows which will swing out. This supplementary window should be small, not larger than 10 by 12 inches. Its opening will be governed by the positions of the hooks which secure



Detailed Vertical Section through Classroom Window Showing the Deflector and Steam Heating Radiator
(Courtesy Frank Irving Cooper Corporation)

it and usually need not be more than an angle of 25 degrees. Transoms, sometimes seen over French windows, afford a better means of ventilation than the movable panes.

In some climates, with some exposures and in some types of building construction, air leakage is such that no windows need be opened in very cold weather, except, perhaps at night. But where storm windows are added in cold weather, these should be made to open. If the storm window is made in one piece, it is desirable to have it swing out from the top except that by this method in severe storms rain or snow would enter between the sashes. To have the window swing out from the bottom is the next best plan. When storm windows can be installed to slide in the same manner as the permanent windows, this is the ideal.

Since windows are coming more and more to serve the main purpose for which they are intended, that of providing satisfactory lighting; and also since the tendency is to beautify windows, or to use a style of window which will frame the best outdoor views as seen from within, it is argued by some that fresh, outdoor air might better be secured in winter through other means, such as a series of inlets in the walls controlled by dampers. But here again we should face the psychological issue which has been so prominent in all ventila-

tion practice: many persons like to see the windows open; they want visible proof that they are getting fresh air. Then, again, there is the practical question to face that so long as fresh air can be secured through the use of windows why introduce another expense for the construction of special air inlets? Where there are no windows the inlets, of course, are essential, as in inside rooms or theaters.

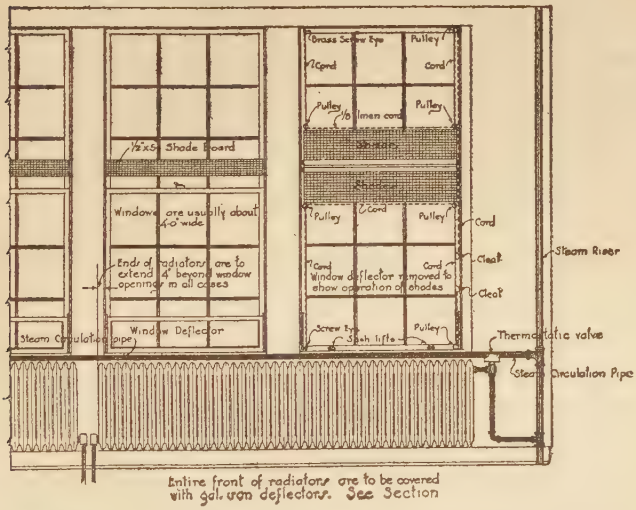
Window Deflectors and Their Uses

Window deflectors furnish a great aid to good ventilation in some instances, such as in schools, offices or elsewhere where there are many occupants in a room and where desks must be placed fairly close to windows. Also in some homes they are an aid, as in bedrooms or where it is necessary to minimize the amount of dust which may enter a room, or for exposures where storms prevent the opening of the windows unless deflectors are used. They are by no means a universal necessity.

Glass deflectors have been regarded the most satisfactory by reliable experimenters. However, the 8-inch deflector which was first introduced has given way largely to the 10- or 12-inch deflector; and there are advantages in having a deflector 15 to 18 inches high.

The metal deflector which has a screen at the top is an advantage in sections where a large amount

of dust and soot makes window opening a hardship. These metal deflectors may be attached either at the bottom or the top of a window. When the



ELEVATION OF CLASSROOM WINDOW SHOWING RADIATOR WITH SPECIALLY DESIGNED STEAM PIPE ALONG THE TOP; SHOWING, ALSO, WINDOW SHADES HUNG FROM THE CENTER OF WINDOWS TO DRAW EACH WAY
(Courtesy Frank Irving Cooper Corporation)

screen becomes clogged with dust it can easily be cleaned with a stiff brush.

Deflectors should tilt at an angle of about 25 degrees from the vertical. Some deflectors are adjustable and may even be placed horizontally in

warmest weather. The usual custom, however, is to remove the deflector in warm weather.

The chief advantage of the deflector over the window which opens on a pivot, is that the window opening can be much smaller; but more important still is the advantage of deflecting the air upwards. Window deflectors, ideally, should be used in connection with radiation which is placed below the windows, in order that the incoming air may be warmed.

Window Boards, Cotton Screens and Other Wind Breaks

The introduction of a board about 8 inches high, under the lower sash of a window has resulted in good ventilation in some instances. Various types of window boards have since been invented, most of which are no better than the original plain piece of lumber. The cotton screen also has served a useful purpose.

Both of these devices have served to get the window open, but quite as much good would be accomplished by opening the window very slightly at the top. These devices call for a wider opening and then partly cover it, whereas a smaller window opening would serve the same purpose, and the inconvenience and trouble of the device would be avoided.

Humidifiers in Wide Variety of Makes

The subject of humidification has been a more or less debated issue. The more recent experiments tend to discredit the importance of humidity.

Humidity increases in importance as the temperature falls. In climates where the temperature falls to 20 below zero the air becomes so dry that when heat is applied to it, artificial humidity is essential to health and comfort and helps to preserve books and furniture.

Humidity may be controlled or increased by two methods: water evaporation and the introduction of hot steam or vapor. Either method must take into account the quantity of air in cubic feet to be saturated and must provide sufficient moisture to accomplish the degree of saturation necessary.

Lyon,[1] of Minneapolis, through the use of a hygrometer, discovered that to secure 50 per cent relative humidity in his residence it required the vaporization of half a gallon of water per hour per 7,000 cubic feet of air. Textbook standards of humidity, he claims, cannot be realized in northern homes. The change of air in the room due to leakage through windows, doors and walls, is such that humidity is removed or reduced very rapidly. Due

[1] E. P. Lyon, "How to Put Humidity into Your House," *Hygeia* (January, 1926).

to this leakage it is necessary in the average home to evaporate 20 to 25 gallons of water every twenty-four hours to get a moderate result.

Small dishes of water for this purpose are insignificant in such a climate. Lyon uses twelve trays 30 inches long, set one upon the other over a radiator. This method he finds the most satisfactory compared with the expense involved. He has used the spray method and advocates this as the most ideal. By this method air is drawn off at the top of the room, passed through a spray concealed in a closet back of the radiator, and returned at the bottom of the room. With the spray method he raised the humidity in two downstairs rooms from 14 and 12 per cent respectively to 49 and 40 per cent of saturation.

Lyon also has used the wick system in which vertical blotters are dipped in water at the lower edge. They are set in a container 6 inches wide and 2 inches deep. "Under favorable conditions one gallon of water per foot of radiator space occupied will evaporate each twenty-four hours."

Lyon does not find that his coal bill is diminished by artificial humidification. The cost of the extra heat required to evaporate the water to provide the humidity is estimated to be ten cents a day. However, he was able to reduce the temperature of his house from an average of 70 degrees F. to 68 de-

grees F. by the control and increase of relative humidity. Also his books and furniture show the difference very beneficially.

The cumbersomeness of the devices described by Lyon will prevent their general use. Electric humidifiers now being perfected should prove an advantage by reason of their simplicity. Two things to remember in the application of humidity are the necessary percentage of saturation (from 35 to 50 per cent is regarded satisfactory) and the outside temperature. As the thermometer approaches zero and goes below this point, the need for artificial humidification is correspondingly increased.

Position of Electric Fan Important

Electric fans often are objectionable because they cause a draft. And they may be ineffective if improperly placed in a room. The most satisfactory method of ventilating a room in summer is through nearly closing the windows in the daytime, keeping the cool night air inside, and by the use of electric fans. Fans should be placed to produce a current of air through the room, in gentle motion but without draft. In window-gravity ventilation, with the outlets near the ceiling to carry off the overheated air, the fans should be placed in the breathing plane, as it is this air which must be kept in motion. A

fan placed too low or too high defeats its purpose or cuts down its possible efficiency.

Fans which revolve from side to side are an advantage over stationary fans in that they introduce the element of variability. If the speed of fans could be changed automatically so that they could be timed to run at full speed for five minutes and then at a lesser speed, this too, would be an advantage.

Refrigerated Air Conquers Summer Heat

The ability to conquer environment is not alone possible in cold weather when indoor temperature may be made comfortable; but through the use of cooling devices, it is also possible to extend this comfort to indoor places in summer.

Refrigerated air, if properly controlled, is an excellent means of providing summer health and comfort. Up to the present time this plan for cooling buildings in summer has not been employed extensively. A few theaters, hotels and banks use it. Without doubt it will be extended to factories, schools and even to homes, especially when electric current is produced more cheaply.

In a large building, refrigeration plants are used so that large quantities of air can be cooled and then forced by fans through ducts to the rooms. For small offices or private homes, the refrigeration de-

vice should be portable so that it can be moved from room to room. The general principle of cooling air by forcing it at high pressure over ice and then delivering it at once to the room is used in portable devices of this nature.

Summary

Double-hung, vertically, sliding windows are best for ventilation. The upper and lower sashes should open independently of each other.

Window deflectors, or baffle boards, are desirable for schools, offices and other places.

Cotton screens and window boards are unnecessary if windows are opened properly.

Artificial humidity is necessary in cold climates, but care should be taken that the device used is giving off sufficient moisture to be of value.

Electric fans should be placed in the breathing plane to be of greatest advantage.

Refrigerated air is an excellent means of providing summer health and comfort.

CHAPTER XI

INSTRUMENTS USED IN VENTILATION

Discovery of the Thermometer

ALTHOUGH Galileo discovered the principle of the thermometer in 1592, Fahrenheit devised the first thermometer scale to give satisfaction, in 1714. The dry-bulb thermometer most commonly used in ventilation in the United States and Great Britain is therefore named for Fahrenheit.

Fahrenheit took for the zero point on his scale the lowest temperature observed by him in Danzig, where he lived. This temperature he found was that produced by mixing equal quantities of snow and sal-ammoniac. The space between this point and that to which the mercury rose at the temperature of boiling water he divided into 212 parts.

Anders Celsius, a Frenchman, devised a scale with the boiling point of water at zero and the freezing point at 100 degrees. Christian, another Frenchman, reversed the points in 1743 and to-day his scale is known as the centigrade scale. The centigrade thermometer is used extensively in Europe, where it is known as the "Celsius" thermometer.

Another Frenchman named Reaumur devised a scale on which the freezing point was at zero and the boiling point at 80 degrees. Reaumur's thermometer is used in Egypt and Turkey.

Centigrade degrees are changed to Fahrenheit by multiplying by nine, dividing the product by five and adding thirty-two.

Reaumur degrees are changed to Fahrenheit by the same process except, in division, four is substituted for five.

Kata-Thermometer Described

The kata-thermometer is a recent invention of Leonard Hill of England. It is designed chiefly to measure the cooling power of the air and the velocity of air currents. It can be calibrated to indicate temperature and humidity as well. It is named "kata" from the Greek meaning "down" as the reading is made as the meniscus goes down.

In describing the need for such an instrument as he has invented Hill states:

The ceaseless variation in the rate of cooling, evaporation, absorption of radiant energy, as in outdoor conditions, relieves us from monotony, stimulates tone and metabolism. Indoors, the conditions are generally uniform, monotonous and unstimulating. In closed, artificially heated rooms, the cooling and evaporative powers are very greatly reduced by the lack of the vastly freer ventilation which pertains out of doors,

even on calm days. The dry-bulb thermometer wholly fails to indicate that this is so.[1]

Vernon describes the Kata-thermometer as follows:

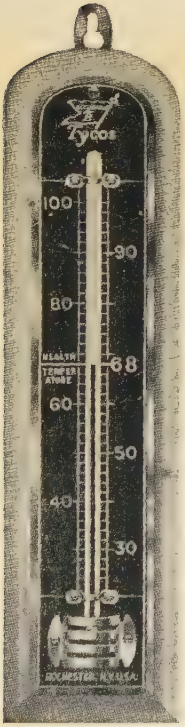
The kata-thermometer consists of a large-bulbed alcohol thermometer. To use it one must first heat this bulb to a temperature above 100 degrees by immersing it in hot water. The bulb is then dried and the time of cooling the thermometer from 100 degrees to 95 degrees (a range roughly corresponding to the temperature of the human body) is taken by a stop watch. The rate at which the thermometer cools depends partly on the air temperature and the velocity of the air currents impinging on its bulb; and as the human body is likewise subjected to the same conditions of temperature and air velocity, it follows that the cooling rate of the thermometer affords information which can to some extent apply to the human body. Moreover, it is possible, by means of a simple formula, to calculate the actual velocity of the air currents from a knowledge of the cooling rate and the atmospheric temperature.[2]

Comparison of the two types of thermometers is given by Hill as follows:

The temperature thermometer indicates the average effect of the temperature of the air and walls of an enclosure on itself. It does not show the cooling and

[1] Leonard E. Hill and Argyle Campbell, *Health and Environment* (Longmans, Green & Co., New York, 1925; Edward Arnold Company, London), p. 170.

[2] H. M. Vernon, "The Kata-Thermometer," *Jour. National Institute of Industrial Psychology* (January, 1925), p. 198.



The Temperature Thermometer with the Health Temperature Plainly Indicated at 68 Degrees F. (Courtesy Taylor Instrument Company.)

The Kata-Thermometer.

Devised by Dr. Leonard E. Hill of England to measure air movement. The mean value as indicated between the two marks on the stem is 36.5 degrees C. (Photograph supplied by Dr. Hill.)

evaporating power of the environment on the skin and respiratory membrane. It is a static instrument while the body is dynamic, producing heat which must be lost to keep the body temperature normal. To measure these cooling and evaporative powers, the kata-thermometer was introduced.

The practical use of the kata-thermometer has been demonstrated in factories to determine whether the atmospheric conditions were suitable to remove the heat produced by the bodies of the workers so that they could be kept comfortable and efficient.

Moreover, Hill states that observations of body-heat production and metabolism during work and rest, as affected by open-air conditions, would not have been possible without the kata-thermometer.

The results of such investigations, Hill believes, show clearly the value of open-air conditions in stimulating body-heat production and vigor, and in greatly increasing comfort during muscular work.

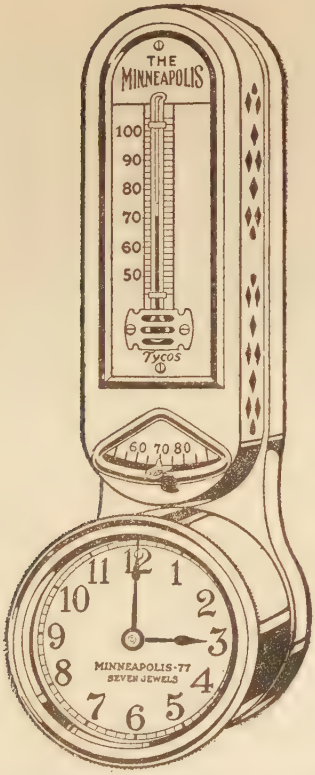
Hill has made some valuable observations in regard to preservation of body heat from loss by exposure such as in shipwreck. He advocates the removal of clothing, wringing it dry, redressing and then the use of an oilskin over the clothing. This prevents further wetting and protects from the wind. Observations with the kata-thermometer as well as observations on the body-heat production of the subject of this shipwreck research, support these

suggestions and show that the saving of body heat by such means is very great.

Development of the Thermostat

One hears a great deal about the thermostat in connection with ventilation. Thermostatic circulation-control devices generally consist of two main parts. The first of these is a bulb and a flexible tube containing the sensitive liquid, chiefly ether. This bulb is held in an iron housing placed in a water-return line. The second part is an expansion drum of flexible copper which is forced open in the manner of an accordion by the action of vapor given off by the contained liquid under the effect of heat. As the temperature varies this drum opens and closes and operates the damper of a heating plant through a system of levers.

Another type of thermostat is operated through a gravity, spring or electric motor. This type of thermostat consists of a thermostatic-metal coil made of two kinds of metals, usually copper and invar. The one side expands with the heat and the other side contracts with the cold. This expansion or contraction makes or breaks a contact which operates the motor. The motor, which is connected by a chain to the draft and check, operates these to open or close them as the room temperature rises or falls (see diagram, p. 171).



THE MODERN THERMOSTAT WITH A REGULATING TIME DEVICE
(Courtesy Minneapolis Heat Regulator Company)

It is claimed for the thermostat that it will maintain an even temperature in a room; that when the desired temperature is attained, 68 degrees F., or any other predetermined temperature, the ther-

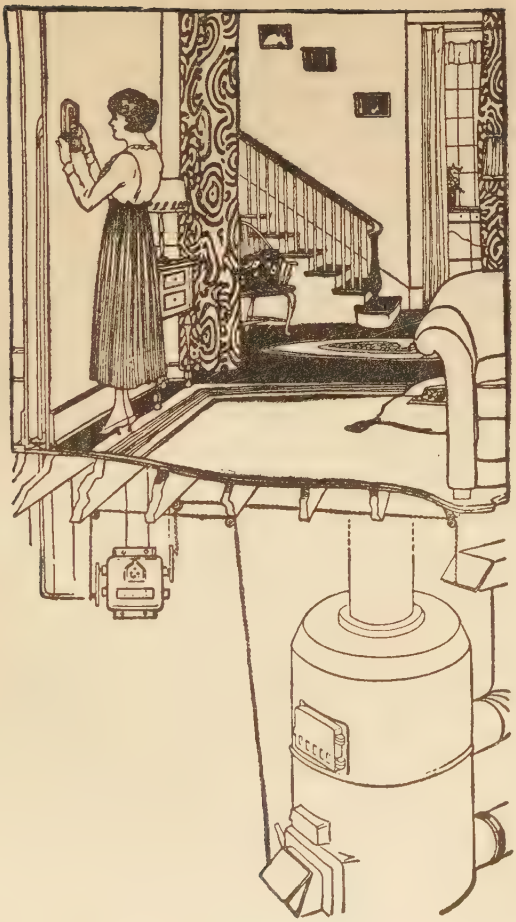
mostat, set for this temperature, will automatically shut off the heat. In practical use many difficulties arise. Chief among the difficulties is that the use of the thermostat presupposes that an "even" temperature is desired. The newer ideas of ventilation call for variability and air movement. These conditions of the air disturb the thermo-regulator and, although so-called "lagging" devices have been contrived, they do not compensate for the external variations which modern ventilation practice demands. While the use of the thermostat may be an aid to ventilation, too much reliance should not be placed upon its efficiency.

Check Thermostat with Thermometer

Winslow[3] relates that "in a certain mechanically ventilated school in New York City . . . where thermostats were carefully adjusted, 143 observations of the room air showed 124 records between 64 and 69 degrees F., with three below 64 degrees F. and only three above 71 degrees F. . . . When the same school was visited a few years later, its temperature control was so imperfect that the experiments contemplated had to be transferred to another building."

Winslow also reports an office building which

[3] C.-E. A. Winslow, *Fresh Air and Ventilation* (E. P. Dutton & Co., 1926).



How the Thermostat Operates to Open or Close the Furnace Draft

(Courtesy Minneapolis Heat Regulator Company)

he studied where 85 offices and workrooms had thermostatic and 147 hand control. There was somewhat greater overheating in the "automatically controlled" rooms than in the others. In one particular room the temperature for a period of twenty-one days in February and March never fell as low as 70 degrees F. during the working hours, and was usually in the neighborhood of 80 degrees F. The reason was apparent when it was found that of 213 thermostats in this building, which were individually examined, 110 or 52 per cent were out of order and not controlling their radiators.

"It is obvious," he concludes, "that even where automatic temperature apparatus is installed its operation must be checked up by thermometer readings."

Heat-Regulating Device Desirable

It should be said in all fairness, however, that a heat-regulating device of some reliable make is a great aid to the control of indoor temperature. Such devices often prevent overheating at times when there is a sudden rise in outdoor temperature. A user of one of these devices, himself a man of mechanical genius, attached a pulley connecting his sleeping-room window with the same device so that when the clock which was attached to the regulator told the hour he desired his furnace draft turned on in the morning, the regulator not only

performed that duty for which it was intended, but closed the window as well. After the clever genius awakened a number of mornings to make sure his device was operating, he soon learned to sleep through another half hour until his room was nicely warm for dressing.

A comparatively new development in thermometry is the indoor and outdoor thermometer. It tells the temperature at two different points at the same time. At the top is a spirit thermometer that records the temperature of the place where the instrument is located. Below is a dial on which is indicated the temperature of any point where the metal tube has been placed. The outside dial is connected with the outside registering tube by capillary tubing. This tubing is filled with spirits and protected by its metal covering; it is said to be entirely free from the influence of the surrounding air or of damage from shock. Such an instrument should prove of great assistance to engineers in the operation of furnaces in cold weather, and consequently become valuable in ventilation.

Many Makes of Hygrometers

An instrument designed to measure the humidity in the air is known as the hygrometer. Humidity is spoken of as "absolute," which means the amount of vapor actually present in the atmosphere; "rela-

tive," which represents the ratio of the absolute humidity when divided by the amount of vapor that might exist if the air were saturated; and "dew point," which has reference to the temperature at which visible moisture begins to be condensed on windows or other cold objects.

There are several kinds of hygrometers. A common type is one which consists of two thermometers. The bulb of one is covered with muslin kept moist through a wick with a container of water. The difference in the readings between the two thermometers when agitated indicates the humidity in the atmosphere. If room air is very dry the difference will be very little and if it is full of vapor, as from a steaming kettle, the difference will be marked.

Hot-Wire Anemometer and Its Use

The anemometer is an instrument which measures the velocity of the air.

H. M. Vernon has experimented with what he calls the "hot-wire" anemometer. He finds that this instrument will measure the velocity of currents coming from any direction, with a fair amount of accuracy. Vernon found that the kata-thermometer was unreliable to measure descending air currents.

The anemometer is a small instrument which

stands upon a table. It is equipped with copper wires which are attached to a battery. As these wires grow hot, a current of air directed against them will be manifest by the visible cooling of the wire. The calibration of the anemometer was accomplished with considerable difficulty, according to Vernon.

In connection with the anemometer, a simple instrument like a weather vane is used to indicate the direction of air currents.

This portable equipment is used in the experimental work of the Industrial Fatigue Research Board of England, Vernon being the chief investigator of ventilation attached to this department of His Majesty's Service.

Summary

The ordinary dry-bulb thermometer, used so extensively in ventilation, was perfected in 1714 by Fahrenheit, for whom it was named.

Since he believes the air movement is quite as important as temperature, Leonard Hill of England invented the kata-thermometer which indicates the cooling power of indoor air.

The thermostat is designed to regulate room temperature by automatic control.

A new type of thermometer enables one to know the temperature at two different points at the same time. It is called the indoor-outdoor thermometer and

should prove an aid to engineers in regulating heating plants according to the outside temperature.

H. M. Vernon of England is experimenting with a new instrument for measuring the velocity of air which he called the hot-wire anemometer. It is a more sensitive instrument than the ordinary anemometer.

CHAPTER XII

EDUCATIONAL METHODS

PUBLIC education is the immediate need in the ventilation campaign. Up to the present, most of the ventilation experience of the country has consisted in gathering the facts about existing conditions and in experimenting with new methods. The scientific investigators have now told us what conditions must prevail to secure fresh air; the practical experts have found a way to secure these conditions, but the general public still is very largely in the dark about these discoveries.

What can Moline, Owosso, Saranac, Denver, Sacramento, Dallas, Augusta, Washington D. C., Baltimore, Jersey City and Brooklyn do about it? Have not all these cities their health agencies, their chambers of commerce, their women's clubs, their parent-teacher associations? Any one of these groups, or, better still, all of them, will think of ways in which a community can be informed about fresh air and ventilation. Such groups can take the essential facts and create so much enthusiasm for fresh air that every window in the place will creak

on its sticky pulleys and rusty hinges. Strong arms will pry open the most unwilling window. There will be jobs for mechanics, both skilled and amateur, for weeks to come, oiling and greasing the slides and pulleys of these windows and planing them off where they have swollen with the weather, too tight to open.

The five and ten cent stores will sell out their supply of thermometers within a week. Even the better grade and more reliable makes of thermometers will be exhausted before the merchants are aware of what has happened. One can imagine a conversation in the average office:

"I always knew we kept it too hot in this office. You fellows won't need to take it from me any longer. The boss has put this thermometer with the zone above 68 degrees F. marked *'Danger'* and the zone below marked *'Health.'* Now we'll be able to know who is right." This from a fresh-air enthusiast. And in the schools the thermometers will be even more welcome.

"What a help it is to know when the temperature in the schoolroom is right!" exclaims one teacher to another.

"Yes," the other replies, "I never think about the temperature once I begin the classwork; but when I go out at noon I feel as though I had been suffocated all morning, the outside air is so different.

I'm going to appoint a pupil from the room to read the thermometer every hour and record the temperature. If the temperature goes above 67 degrees F. we'll open our windows wider before it has a chance to reach the danger zone," this teacher continues.

A fresh-air and ventilation campaign should be one of the easiest health projects to promote. Every one is interested, or will be when it is understood what a vital concern fresh air is to the health of all. More babies will be put in the fresh air to sleep and to play; more toddlers will be released from hot kitchens to fenced-in porches or sand boxes where, well wrapped, they can be happy in fairly cold weather. But better still, all rooms of the home will be kept well aired at all times so that every one may enjoy fresh air. The housewife needs it most of all. Her kitchen should always have windows open to some extent.

Fact Gathering

When the general fundamental truths about ventilation are absorbed by the community, it is a good plan to see how near the homes, schools, factories and other indoor places come to having fresh air. Possession of the actual facts will prove a publicity weapon to convert the most ignorant and skeptical persons.

You Can Keep Well—

The Responsibility of Personal and Public Health is the Concern of Every Individual.

Your Health and the Health of Your Family Will be improved if you will carry out the following suggestions·

Keep a reliable Health Thermometer in your room or office Place it at your sitting height away from windows or radiator Read it every hour Regulate room temperature to comfort and 68 degrees by opening or lowering windows at the top.

See to it that there is movement of air. Hot, vitiated, bad air, will rise to the ceiling, and should be let out. In case there is no outlet near the ceiling in the wall, windows should be opened very slightly at the top. At least one window in every room should always be kept slightly open at the top.

See to it that there is always moisture in the air through constant evaporation. This can be provided for by keeping full water pan in the furnace, keeping steaming tea kettle on the kitchen range, keeping pans filled with water on top of radiators or registers. Plants frequently watered also aid.

For Further Information
CALL STONE 860

Tuberculosis and Health Association
33 CHESTNUT STREET
ROCHESTER, N. Y.

FRESH AIR INDOORS

What it is;
Why we need it;
and How we can secure it.

Statistics show that one out of every four persons suffers from a cold at least once during the year.

The lack of fresh air indoors is one of the contributing causes of common colds.

Neglected colds frequently develop into pneumonia.

One fifth of all deaths are from respiratory diseases.

FACTS PRESENTED BY
FRESH AIR INDOORS COMMITTEE
of the
TUBERCULOSIS AND HEALTH
ASSOCIATION

LEAFLET USED IN VENTILATION CAMPAIGN BY TUBERCULOSIS AND PUBLIC HEALTH ASSOCIATION OF ROCHESTER, NEW YORK

Outside Pages

Determine what school temperatures actually are, under the various systems of ventilation used, by recording hourly temperatures for a month in winter.

Then get some records from factories and of-

"Bad Air" is Harmful

"Bad Air" diseases flourish because people have ceased to live in the open air, and are too completely protected from the weather in enclosed heated houses. It is not the lack of oxygen, nor the presence of carbon dioxide, but overheating that makes air bad.

Bad air is overheated air, without sufficient humidity "moisture content," and movement.

OVERHEATED AIR

Causes Mental and Physical Depression:

The temperature of the body increases, as does the heart rate, and the rate of breathing.

There is a fall in the general tone of the circulatory system.

Reduces Mental and Physical Efficiency:

Causes dry sensation in the nose, throat, respiratory tract, and skin, and general irritability.

Lowers Body Resistance and Increases Susceptibility to Colds:

Weakens functions of membranes of the nose and throat, and deadens body sensation to heat and cold. In the process of artificially heating air, temperature increases and moisture is removed. This causes body skin and membranes to become dry.

"FreshAir" is Health-giving

Fresh air is not a discovery of today or yesterday—its just something good and old and necessary, which we all neglect in the hustle of our daily lives and which we must pay heed to if we would "keep well, live longer, and serve better."

Fresh air is air that is cooler than 69 degrees, in motion, variable, and moderately moist.

FRESH AIR

Stimulates Mental and Physical Vigor.

The temperature of the body is kept cool at a room temperature of 66 degrees.

There is a general feeling of freshness such as one experiences while out of doors.

Increases Mental and Physical Efficiency

With air in motion the stagnant air around the body is replaced with a refreshing effect.

Increases Body Resistance and Reduces Liability to Colds.

With slight fluctuations in temperature from 66 to 68 degrees, and with a relative humidity of from 40 to 50 degrees, the membranes of the nose and throat function with maximum effectiveness and sudden chilling or heating of the body is avoided.

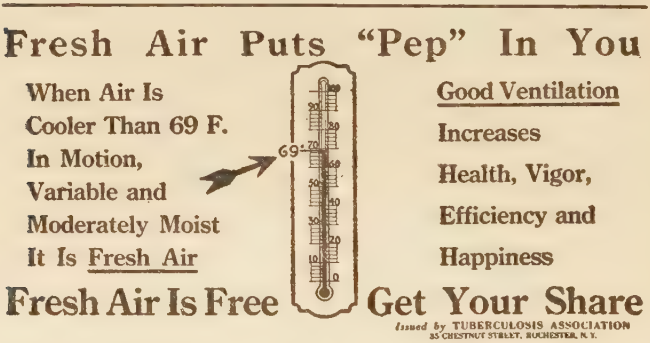
LEAFLET USED IN VENTILATION CAMPAIGN BY TUBERCULOSIS AND PUBLIC HEALTH ASSOCIATION OF ROCHESTER, NEW YORK

Inside Pages

fices. Public-health nurses will know the average condition of homes. Records of temperatures in theaters and churches are easily secured. Perhaps the chamber of commerce and some hotels and clubs

provide rooms for luncheon meetings or late afternoon committee meetings or conventions. Get their average temperatures for such events.

"We can't hold any more meetings at the Ray Hotel," one chairman will announce to his committee some day. "This is the only room available and windows in here can't be opened without a draft.



STREET-CAR POSTER USED IN VENTILATION CAMPAIGN BY TUBERCULOSIS AND PUBLIC HEALTH ASSOCIATION OF ROCHESTER, NEW YORK

The temperature to-day is just under 80 degrees F. The management says that nothing can be done to reduce it."

"I'm absolutely cooked when I get out of this club after luncheon," announced one man. "Some of the fellows seem to like that hot, smoke-filled air. It makes me incapable of doing the clear think-

ing that's expected of me when I get back to my office. I think it is harmful and I'm going elsewhere for luncheon after this."

Exhibits and Lectures

Talks on fresh air and ventilation may become a part of the programs of organizations interested in educational and welfare work.

Exhibits are even more effective. Recently the National Tuberculosis Association conducted a contest for merchants who made the best window displays to illustrate the importance of ventilation, photographs of the exhibits to be sent to the Association with full description of the exhibits.

Contrasting effects of fresh air and overheated air offer splendid opportunities for visual education. Expositions, county fairs, store windows and public corridors are suggested among the desirable places for such exhibits.

Suggestions for Thermometer Exhibits

1. Thermometer, 5 feet high, constructed of board or metal, 68 degrees F. marked in red. Electrically controlled ball to represent mercury slowly rising until 68 is reached, when an alarm sounds.
2. Two thermometers, each to be at least 2 feet high; mercury shown in one at 65 degrees F. Beside this thermometer place a vase of fresh flowers. The second thermometer to be marked 75 degrees

F. Beside this thermometer place a vase of wilted flowers. Legend for exhibit: *Children, like flowers, thrive in the cool, fresh air, but wilt in overheated air.*

3. Thermometer of regular size with 68 degrees F. marked in red, similar to new style thermometer now recommended for schoolroom use. Have thermometer suspended over a desk in position recommended by New York State Commission on Ventilation. This exhibit will be improved if a wax figure can be borrowed from a department store and posed as the teacher, seated at the desk. Legend: *Place the thermometer near the center of the room over the teacher's desk.*

Models for Exhibits

1. Model of schoolroom with modified window ventilation. This model room could be prepared by the public-school manual-training department. It should show windows open at the tops very slightly; radiators under the windows with hand-controlled modulating valves; a duct at the top of the inner wall near the ceiling, controlled by a shutter. A miniature thermometer should register the proper temperature.
2. The "breathing dolls." This graphic presentation of fresh air versus stagnant air is a mechanical exhibit owned by the Illinois State Department of Health. It was designed some years ago by St. Clair Drake. This exhibit shows two sleeping rooms, one above the other. Each is fitted completely, and dolls are shown in bed. One sleeping room has its windows open and the other

has its windows closed. Smoke is pumped into both rooms, to represent the breath. In the room with open windows it passes out quickly and in the other it remains. The use of this exhibit has been restricted due to its expense. The cost is something like $350 and it requires a motor and current to operate, or else it must be operated by an individual.

3. Models to contrast the old and the new way of ventilation with captions and legends to explain the differences fully.

Suggested Community Studies

Since ventilation work is so new and since it still is regarded as an unsolved problem, each community should establish a research department in connection with its fresh-air and ventilation campaign. The objects of such research work might include:

1. *Health and Efficiency Studies*

Repetition on smaller scale perhaps of some of the experiments of the New York State Commission on Ventilation to show the effect of good and bad ventilation on health and efficiency.

2. *Economic Studies*

A study of the use of fans in schools especially where mechanical ventilation is in use. This would include the hours during the day when the fan is operated, the days during the week and the weeks during the year. It would include a study of the cost of operation, per cubic foot, for various types of buildings.

3. *Mechanical Studies*

Since it has not been completely demonstrated whether it is better to open windows from the top or from the bottom; whether it is necessary to have duct openings as large as 8 feet square or whether smaller openings will give as good results; whether humidity is amply supplied by reason of open windows or whether a moderate amount would better be added; all of these points in connection with modified window ventilation suggest interesting and profitable studies.

Probably we shall not be able to improve upon the definition of fresh air, but as to the methods we take to secure it, there doubtless is room for much improvement.

Conference Groups

Conference groups will be found helpful to discuss community problems in ventilation. Teachers, factory managers, theater managers, ministers, social workers represent some of the groups that have ventilation problems to solve.

While it can be assumed that the need for fresh air and for better ventilation is general, specific problems will make the interest more vivid. Such questions will come up as: "What can we do to ventilate our school while we are waiting for the best system to be installed?" or "We have shut off our mechanical ventilating machinery and now we have nothing to go by; what is the best plan for opening windows?"

"How can we get fresh air to our workers in a department which requires freedom from dust?"

"When the ventilation of our church is good near the open windows, it is too warm in the center of the auditorium. What shall we do about it?"

"How can we ask families to keep windows open when fuel is high and they haven't enough bedding to keep warm?"

Any number of such questions will arise which will convince the committee that general education in regard to fresh air will be fruitless unless some provision is made for the solution of definite problems.

The project method which has met with success in other fields should prove just as successful in the ventilation field.

Some one who is thoroughly familiar with modified window ventilation and who has accepted the modern scientific view of ventilation, should be secured by the committee to demonstrate how these various problems can be met so that fresh air can be delivered to the occupants of any room at all times.

What to Teach in Ventilation

Most of the textbooks on physiology emphasize the older theories of ventilation which have been discarded following later scientific experiments.

With this in mind it is well for the teacher to look over the material presented in the physiology or hygiene text used, to make sure that the teaching contained is in accord with the newest scientific ideas on the subject.

Some experiments which have been recommended as an aid to understanding the importance of ventilation should no longer be employed. Such an experiment is the one in which a lighted candle is perceived to be extinguished when placed in a jar where the oxygen supply is deficient. This classic experiment has been employed to show that oxygen is the important essential in air that is breathed and in its absence life is not sustained. This fact is indisputable but its implication places a wrong emphasis on the teaching of ventilation. Oxygen in quantities sufficient to support life is found everywhere even in the most crowded and illy ventilated rooms. Newer experiments need to be devised to show that cool air is the essential thing in good ventilation.

Two boxes might be constructed, one to be supplied with ice to keep it cool and the other kept at a temperature of 75 to 80 degrees F. Place a rose, or other flower in each of the two boxes. Observe that the flower in the warm box is soon withered whereas the flower in the cool box remains fresh for a long time.

According to the newer knowledge of fresh air, it is the air we live in and not so much the air we breathe that is important to health. In consequence we should cease our discussions of "pure air" and "the air we breathe" and center our conversation upon "cool air" and "the air we live in." Air that smells sweet and clean is desirable and yet we should not be misled by the conception that odors affect health except that they may decrease the appetite for wholesome food. Nevertheless, this is a matter for serious concern. But those who have been taught an appreciation of cool, fresh air, will doubtless demand that it smell fresh and clean.

Methods of keeping air cool and of testing its coolness should be among the important studies. But first of all a consciousness and an appreciation of fresh air should be aroused in children. This can be begun in the kindergarten through songs and dances and play in the open air, with windows open and the fresh air freely blowing in as the children play about.

Suggested Graded Study in Ventilation

Kindergarten and Grade 1	Learn to appreciate fresh air through songs, poems, stories and dances.
Grades 2 and 3	Learn value of open windows and play in the open air. Special study of the life of the bee and how the hive is ventilated.

Grades 4 and 5	Learn characteristics of good and bad air. Learn to read thermometer.
Grades 6 and 7	Learn how to open windows and to help condition room air; to keep temperature chart.
Grades 8 and 9	Physiology of respiration. Instruments used in ventilation. How to operate a boiler. Stories: Black Hole of Calcutta. Steamer *Londonderry.*

Ventilation Literature

Many organizations and groups have issued literature on the subject of ventilation. The Rochester Tuberculosis Association was one of the first community organizations to use the facts presented in the report of the New York State Commission on Ventilation in a community compaign.

A street-car poster was designed stating clearly the qualities which air, to be fresh, must possess (see illustration).

Bulletins were sent to all schools and factories warning against the dangers of high temperatures and giving a summary of the Commission's findings.

Several factories in Rochester have installed modified window ventilation but so far it has not extended to schools, chiefly because of ventilation laws.

State and national health agencies have issued

"The Joy of Fresh Air."

From a pamphlet issued by the National Tuberculosis Association.

literature on ventilation, most of which has been confined to attractively illustrated recommendations and challenges for open windows. One gathers from reading this literature that all windows should be wide open, top and bottom, day and night. It is to be hoped that the exaggerated form of instruction will result in getting some windows open slightly at either top or bottom some of the time.

The emphasis in education should be upon proper temperature, air movement and humidity first, and then upon the methods by which these are obtained, having due regard for the climates prevalent in different sections of the country.

Leaflets on ventilation work as in other campaigns should be addressed to specific groups, as to school children, factory employees, or home makers.

Mention has been made of the pamphlet issued by a large insurance company for school janitors. This is an excellent idea and this particular bulletin has called out a surprising number of requests from school officials for additional copies of the pamphlet for use of school teachers and many requests have also been received by the company for advice to help in solving local problems of ventilation.

It is particularly desirable to help the janitor in his problem of heating because heating has such an important relation to ventilation.

In any building the engineer is decidedly a mem-

ber of the ventilation personnel. Firing is considered by William E. Watt a most essential part of modified window ventilation. Mr. Watt has drawn up some interesting suggestions for firing.

General Rules in Firing

(For steam or vapor heating)

Study the boiler to get the heat needed with the smallest possible fire. Vary your heating with the weather. Heavy firing is hard work and produces more ashes. Firing too heavily melts ashes; melted ashes are clinkers. Too much heat hurts the boiler and is costly.

Keep the pressure down. Ten pounds of steam pressure in the heating plant of a moderate-sized school building has been known to blow water into the radiators and thus retard heating. Have the size of the building in mind in regulating the pressure. Test radiators to make sure the pressure is such that water will not enter them.

Another reason for keeping the pressure down is that too hot a fire will necessitate opening windows too wide. Temperature will get beyond control one way or the other. Heat up gradually and keep fires checked.

Check all dampers in front of the boiler so that no draft can get to the fire the moment room temperature reaches 60 degrees F. Room occupancy will soon raise this temperature to 65 degrees F.

When firing or removing ashes, close check to prevent gas escaping to basement and up the stairs.

Keep fires banked during the day, except in coldest

weather when more heat may be needed in the late morning, or middle of the day.

A slight opening in the ash-pit door will raise a gentle vapor to increase the warmth of the rooms without overheat. The water gauge will indicate when vapor pressure is secured. When heat enough has gone into the pipes, close the ash-pit door.[1]

Watch Weather Reports

Likewise, in the operation of the heating plant, weather reports should be read and supplemented by outside thermometer readings. The pounds pressure of steam delivered to the building to be heated should take into consideration this outside temperature.

This suggestion will come as a comparatively new idea to most engineers who operate the heating plant in cold weather generally in a uniform manner, making little if any variation in control in relation to daily variations.

The operation of ventilation for an auditorium is the most difficult of the situations where fresh-air ventilation is used. The person in charge will need to remember that a temperature of 60 degrees F. will seem warm to those entering the room from the outside and that in such a room, a considerable group of persons, all having a body temperature of 98.6 degrees F. will soon raise the room temperature. Therefore the temperature of the room, when it is

[1] W. E. Watt, Rochester Health Bureau (pamphlet, 1924).

opened, should never be higher than 60 degrees F., and after the group has assembled measures should be taken to control the rise in temperature which will subsequently occur.

It is a fallacy to suppose that a warm room can be benefited to any considerable extent by opening windows at periods during the singing as is a practice common in some churches. The temperature should never become so high that this practice becomes necessary.

The ventilation of a large auditorium with several galleries may require the attention of more than one person during the evening. Under most circumstances, however, one individual, after he becomes used to his plant, can take care of the ventilation of an auditorium successfully.

Constant Vigilance Necessary

Wherever there is a building to be ventilated some one must be in charge of the air conditions if the best results are obtained. Written instructions should be supplied to the ventilation supervisor of every building so that he may know what the management expects. Verbal instructions often are misunderstood. Suggestions for the proper ventilation of every schoolroom and auditorium should be posted somewhere in the room. The problem is difficult and every possible help should be provided to solve it.

"What in one word is the chief problem in ventilation?" some one may ask as the conclusion of this discussion is reached.

"Overheating," is the answer.

The avoidance of overheating is the primary essential in all systems of ventilation. Air change, direction of flow, and all other factors are secondary. The most important article of ventilation equipment is the thermometer; and however complex an apparatus may be installed for air conditioning, a constant and intelligent vigilance in regard to operation and overheating is the price of health and comfort.[2]

Summary

Public education is needed to help promote up-to-date scientific theories and practice of ventilation.

Communities would benefit by ventilation studies to reveal the problems which exist.

Exhibits and literature should be carefully prepared to present essential facts such as low-temperature requirements, not merely open windows.

The project method in which good ventilation practice is demonstrated should be a part of the educational campaign.

Weather reports and outside thermometer readings are important helps to the janitor.

Constant vigilance is the price of good ventilation.

Avoid overheating at all times.

---

[2] *Report of New York State Commission on Ventilation* (E. P. Dutton & Co., 1923), p. 529.

GLOSSARY

Adenoids.—Resembling a gland. In the plural, hypertrophy of the adenoid tissue that normally exists in the nasopharynx of children and is known as the pharyngeal tonsil.

Atmospheric pressure.—This is the pressure due to the weight of the atmosphere. Normal atmospheric pressure is 14.7 pounds per square inch. The average atmospheric pressure for any locality depends on the altitude above sea level.

Blower.—A ventilating fan.

B. t. u. (*British thermal unit*).—The quantity of heat required to raise 1 pound of water 1 degree F.

Calorie.—The Continental heat unit, or calorie, is the quantity of heat required to raise the temperature of 1 kilogram of water 1 degree C., and as 1 kilogram is equal to 2.205 pounds and 1 degree C. is equal to 1.8 degree F., it is obvious that one calorie measures the same quantity of heat as does 3.969 B. t. u. This is shown by multiplying 1.8 by 2.205.

Calorimeter.—An apparatus for measuring quantities of heat.

Cervical glands.—Lymph nodes on each side of the neck.

Chorea.—St. Vitus' dance, a convulsive nervous disease.

Circulatory equilibrium.—A condition in which the circulation of the blood is balanced.

CO_2.—Symbol for carbon dioxide, which is the result of complete combustion of the carbon in fuel.

Cutaneous.—Pertaining to the skin.

Deflector.—A slanting board or glass fitted to a window to deflect the air upward when the window is opened.

Dynamometric test.—A measure of muscular effort by means of an instrument called a dynamometer which embodies a spring to be compressed by the force applied, combined with an automatic recorder, to show the work performed.

Flue.—A passageway for conducting a current of air from one place to another.

Gravity exhaust.—Drawn out by force of gravity.

Individual ducts.—Ducts which connect each room separately with the ventilation system.

Kata-thermometer.—An instrument to measure air movement.

Malnutrition.—Imperfect assimilation and nutrition.

Meniscus.—The surface of a liquid column. Its curvature is determined by the surface tension, being concave when the containing walls are wetted by the liquid and convex when not.

Metabolism.—Tissue change; the sum of all the physical and chemical processes by which living organized substance is produced and maintained and also the transformation by which energy is made available for the uses of the organism.

Morbific matter.—Causing disease.

Motility.—Quality of being motile, capable of spontaneous movement.

Organic effluvia.—Organisms, as bacteria and other matter erroneously thought to flow out through the breath.

Ozone.—A gaseous substance obtained by the silent discharge of electricity in air or oxygen and by other methods.

Plenum air chamber.—An enclosed space into which air is forced so that the outward pressure of the air in the space is slightly greater than the inward pressure from the outside, and leakage is outward instead of inward.

Plenum fan.—Ventilating device connected with the plenum air chamber to force air into ducts connecting rooms with the chamber.

Respiratory exchange.—The process in which the air is drawn into the lungs to supply the blood with oxygen and to remove the excess of carbon dioxide from the blood and lungs in exhalation.

Superficial capillaries.—The very fine blood-vessels nearest the surface.

Ultra-violet rays.—Those invisible rays of the spectrum which are beyond the violet rays.

Vasomotor.—Presiding over the movements of the walls of blood-vessels, *i.e.*, their expansion or contraction.

"Vitaglass".—A trade name for a patented-process glass through which the ultra-violet rays will pass.

INDEX

Acclimatization, 29
Adding, dependent upon temperature, 24
Adenoids, 20, 21
Air, comparison of, 36
  effect on health, 19, 20, 21
  effect on mental work, 22, 23, 24
  fit to live in, 45
  fresh *vs.* clean, 8
  functions of, 46, 47, 48
  temperature of, 36
  volume of flow, 52, 55
  when fresh, 1
  worst in lungs, 35
Air chart, fallacy of, 48, 77, 78
Air hygiene, difficult to observe, 13
  promoted by Billings, 13
American Association for Labor Legislation, 126
American Child Health Association, survey, 63, 110
American Public Health Association, resolutions, 51, 52
American Society of Heating and Ventilating Engineers,
  Code of Minimum Requirements of Buildings, 77
  "compulsory ventilation," 48
  study of heat and humidity, 40
Anemometer, Vernon's hot wire, 123, 174
Art of procuring pleasant dreams, 142

Babson, Roger, ill effects of indoor life, 30
Bacteria, negligible in ventilation, 49
Banks, ventilation of, 135, 136
Billings, John Shaw, effects of bad air, 13
Billings, Mitchell and Bergey, harmlessness of organic matter in expired air, 42

Black Hole of Calcutta, deaths in, due to oppressive heat, 37-39
Bureau of Mines, study of heat and humidity, 40
Burnham, William H., temperature and mental efficiency, 23-24

Calorimetry, contributions to ventilation, 47
Carbon dioxide, floor exhaust useless to remove, 75
harmless to health, 35
Lavoisier's discovery, 33
negligible in ventilation, 36, 49
outworn theory of, 54
Pettenkofer's measure for, 34
rises when heated, 74
Catarrh, induced by bad air, 10
Celsius, 164
Centigrade scale, 164
Chapin, Charles V., discredits air-borne infection, 43
Chocolate dippers, health of, 27
Churches, ventilation of, 137
Climate, effect on death rate, 5, 6
Clark, W. Irving, ventilation program of industrial physician, 127
Code, for ventilation of school buildings, 77
of New York City, 81
of Wisconsin, 69, 81, 82
Colds, caused by overheated air, 10
drafts and colds, 12
less in Evanston schools, 108
less in open-air rooms, 19
Coleman Street School (Gardner, Mass.) temperature study, 108-110
Comfort, opinions unreliable, 3
"Compulsory ventilation," not justified, 48
Contact infection, supercedes theory of "air-borne" and "dust-borne" diseases, 44
Cooper, Frank Irving, architect's experience with ventilation of school buildings, 95, 96
Cost, of ventilation compared, 147, 148
of ventilation due to overheating, 148, 149
to install, 144-147
to operate, 57
Crawfordsville experiment, 78

"Crowd-poison," theory discredited, 37

Death rates, influenced by temperature, 6
Deflectors, 91, 94, 140, 156, 157, 158
Diseases, augmented by overheated air, 14, 15; not "air-borne," 43
  prevented by ultra-violet rays, 11
"Downward" system of ventilation, law to make compulsory, 74
Drafts, big *vs.* small, 7
  colds from, 12
  deflectors to prevent, 91, 94, 140
  distinguished from air in gentle motion, 6
Ducts, 59, 60
  covers for, 98
  in inside rooms, 116
  location, 97
  material to use, 98
  sizes, 97
Dust, negligible in ventilation, 49
  removal of, 61

Eastman Kodak Company, experience with window-gravity ventilation, 114-120, 127
Electric fans, how to place, 161, 162
Elizabeth McCormick Memorial Fund, 85, 87
England, equipment used in ventilation study, 175
  good ventilation increases factory output, 122, 124
  government study of ventilation, 121
Evanston, experience with window-gravity ventilation, 87, 147
Exhaust ducts, should be at ceiling, 55
  size of, 94, 96, 97
Eye disorders, traceable to overheated air, 21

Factories, architectural difficulties, 113
  benzol fumes removed, 114, 115
  Eastman Kodak Co., 114-120, 127
  in England, 121, 122, 123
  industrial physician, 126, 127
  steel plants, 121
  temperature hazards, 126
  temperature standards, 125

Factories, use of two-way duct, 113
Fahrenheit's scale, 164
Fairfield, Conn., Wheeler home ventilated, 138
Sherman School saves fuel, 147, 148
Fatigue, induced by high temperature, 14, 17
Firing, rules for, 192, 193
Franklin, Benjamin, 142, 143
Fresh air, asset to trade, 133
Catholic school has, 88
colds reduced by, 19
cranks, 140
definition of, 1
education for, 179-191
effect on body, 16, 48
fresh *vs.* clean, 8
fresh air *vs.* draft, 11, 12
functions of, 8
in sleeping room, 142
invigorating effect of, 10
laws defeat, 69
necessary to health, 15
school principal crusades for, 85
stimulation to skin, 11
window-gravity ventilation provides, 62

Galileo, 164
Gardner, Mass., temperature study, 108-110
Health defects, extent among U. S. school children, 20
traceable in part to bad air, 21, 22
Heart disease, 2, 8
economy of heart action, 3
Heat and humidity, 40, 41, 42
cause of death, 39
stagnation, 23, 45
Heat regulators, 172, 173
Hermans, 44
Hill, Leonard E., catarrhal complaints, 12-13
comfort opinion unreliable, 3
defines fresh air, 1
favors outside air and radiant heat, 62
fresh air and respiratory disease, 17, 18
functions of fresh air, 8
heat stagnation only cause of discomfort in crowded places, 45
Hoobler, B. Raymond, effect of air on body, 46, 47
Hot-wire anemometer, 123, 124
House ventilation, faulty construction, 25
by window-gravity, 138-140

House ventilation, study reported by Children's Bureau, 26
Hubbard, Thomas, extravagance in overheating, 148, 149
Humidifiers, 159-161
Humidity, experience of E. P. Lyon, 159-161
lessening, 117
neutral zone, 4
studies by Vernon, 124
Huntington, Ellsworth, effect of outdoor temperature on death-rate, 6
Hygrometer, 174

Industrial Fatigue Research Board, studies in ventilation, 121, 122
Industrial hazard, of high temperatures, 126, 127
shifts to reduce, 27
industrial physician, to supervise ventilation, 127
Inside rooms, how to ventilate, 116

Janitor, importance in ventilation, 102
Japanese, work in cool air, 120
Jarvis, Edward, danger to children of unventilated schoolrooms, 39
Joint Committee on Health Problems in Education, endorses window-gravity ventilation, 49, 50

Kata-thermometer, description of, 123, 165-167
ultra-violet rays protect from disease, 11
Kober and Hayhurst, high temperatures in industry, 126

Lavoisier, 33
Laws, *see* Legislation
Lee, Frederic S., "keep cool," 7
physiological problem of ventilation, 45
Legislation, against open windows, 79
in Arizona, 126
based on outworn theories, 66
compulsory ventilation for schools, 66
defeats fresh air, 71
in Delaware, 126
for factories, 79, 80
inconsistencies of, 72
in Wisconsin, 69

Legislation (continued)
makes floor exhaust compulsory, 74
meaningless, 71
in New York City, 81
revision recommended, 51, 52
status of, 70
Lehmann & Pederson, temperature and mental efficiency, 23
Longfellow School, Bridgeport, first example of window-gravity ventilation, 62, 90, 92
"Londonderry," deaths on ship due to oppressive heat, 38, 39
Lusk, Graham, fresh air and metabolism, 7
Lyon, E. P., experience with humidifiers, 159, 160, 161

Malnutrition, traceable to bad air, 20
McLure, John R., engineers attempt to take over functions of health authorities, 78
high cost of mechanical ventilation, 144, 145, 146, 150
inconsistencies in laws, 72
McLure, obsolete standard of ventilation, 76
mechanical systems idle, 77
schools in grip of misconceived laws, 76
Mechanical ventilation, costly to operate, 57, 58
costs, 144-150
harmful to health, 51
individual duct system preferable to trunk duct system, 56
induces colds, 19
laws protect, 67-70, 74
new system of, 59
recirculated air has discomfort possibility, 59
standard for, 34
"Unit" system, 57
violates scientific principles, 54, 55
"washed" air of doubtful value, 58
Memory performance, dependent upon temperature, 24
Mental work, affected by temperature, 22-25
Metabolism, effect of wind on, 7
Methods of Investigating Ventilation and Its Effects, study by H. M. Vernon, 122

Methuselah, housed in open-air, 142
Metropolitan Life Insurance Company, pamphlet for janitors, 102
Mezzanine floor, ventilation of, 134, 135
Milbank Memorial Fund, purpose of ventilation work, 73
Modified window ventilation, inspired by open-air school, 83
  model for exhibit, 184
  recommended by Joint Health Committee, 50, 51
Motion-picture theaters, ventilation of, 134
Mouth-spray, danger from slight, 44
Muscular strength, affected by temperature, 24
Myers, Charles S., plenum fan system needs to be reversed, 122

National Institute of Industrial Psychology, 122
National Institute for Medical Research, 11, 15
National Tuberculosis Association, 183
Natural "upward" ventilation, 62
New York City, ventilation code, 81
  mechanical equipment idle in schools, 149
New York State Commission on Ventilation,
  carbon dioxide unimportant, 35
  constant vigilance urged, 118
  effect of temperature on mental efficiency, 22, 23
  favor window-gravity ventilation, 49, 62
  over-heating chief danger, 14
  ozone of doubtful value, 59
  size of exhaust duct, 96
  study of schoolroom ventilation, 18, 19

Odors, how dispelled, 115, 116
  masked by ozone, 58
Office buildings, how ventilated, 130-132
One-room schools, how to ventilate, 100
Open-air schools, inspired window-gravity ventilation, 83
  temperatures of, 2
Open windows, advised by Franklin, 142

Open windows, deflectors for bottom of, 153
education for, 177, 178, 184
endorsed by A. P. H. A., 52
favored by Joint Health Committee, 50
for fresh air, 1
following crusade, 141
from tops, 153
prohibited by law, 67
recommended by New York State Commission on Ventilation, 49, 62
"Organic poisons," discredited, 54
Our Lady of Sorrows School, ventilation of, 87
Over-fatigue, traceable to bad air, 27
Overheating, avoidance of in factory, 118
determined by pulse frequency, 3
extravagance of, 148, 149
harmful effects of, 14
in offices, 130
in "standard" ventilation, 54
janitor responsible for, 111
Overheating, problem of ventilation, 195
pupils collapse from, 39
Ozonators, 58
Ozone, endorsement of, withheld, 59
of no practical value in ventilation, 52
used to mask odors, 58

Palmer, George T., contrasts "draft" and "breeze," 6
contrasts "dryness" and "dryingness," 4
contrasts "fresh air" and "clean air," 8
Pettenkofer, discredited carbon dioxide theory, 35
established measure for carbon dioxide, 34
Plants, of no practical benefit in ventilation, 101
Pneumonia, importance of fresh air in cure, 2
Posey, W. C., eye disease from sinus trouble, 21
Posture, incentive to brace up lacking in bad air, 21
Pullman cars, ventilation of, 80
Pulse, frequency to determine overheating, 3

Pulse, rises when temperature exceeds 68 degrees F., 22

Radiant heat, best for ventilation, 62, 196
Reaumur, thermometer scale, 165
"Recirculated" air, 58, 59
Refrigerated air, aid to summer ventilation, 162
Respiratory disease, prevention of, 17, 18, 19, 29, 51, 52
Rochester, church ventilation, 137
  educational work, 190
  factory ventilation, 114-118, 127
  theater ventilation, 137
Rosenau, Milton J., effects of drafts, 6, 12
Rural schools, ventilation of, 100

Sawyer, William H., 127
School Children, health defects among, 19, 20
  mechanical ventilation harmful to, 51
  mental alertness at different temperatures, 25
  respiratory affections, 18, 19
Sick benefits, reduced by good ventilation, 119
Sickness, reduced by good ventilation, 119
Sherman School, Fairfield, Conn., ventilation of, 90, 92, 147
Skin, air we live in more important than air we breathe, 45
  blood vessels of, 12
  effect of air upon, 8, 16, 46
  problem in ventilation, 45
Sleeping rooms, how to ventilate, 141, 142
Steel plants, provide cool air for workers, 121
Stores, how to ventilate, 133
Supervision of ventilation, 51, 102, 103, 117, 118, 127, 132, 194
Swivel nozzles, used in ventilation, 59

Temperature, accidents due to, 125
  death rates influenced by, 6
  difference between effect of summer and winter, 28
  effect of 75 degrees F. on body, 14

Temperature, effect of mental work, 22-25
effect on industrial workers, 27
excessive, 44
industrial hazard, 126, 127
in pre-heating, 110
legalized, 66
lower for children, 2
maximum for health, 2
omitted in laws, 82
of fresh air, 2
records, 108, 109
rise in body temperature and disease, 14, 15
standards for, 125
studies suggested, 180-182
survey in eighty-six cities, 110, 111
treatment of disease, 2
Temperature charts, use of, in schoolrooms, 102, 104
Theaters, ventilation of, 136
Thermometer, Centigrade, 164, 165
discovery of, 164, 165
education in use of, 178, 179
exhibits, 183, 184
Fahrenheit, 164
Indoor-outdoor, 173
Pequot school, use of, 102
self-registering, 117
Thermostat, development of, 168-172
Thomas Snell Weaver High School, ventilation of, 96
Thorndike, E. L., mental tests in various temperatures, 22
Tuberculosis, indoor disease, 21
fresh air helps cure, 21

Ultra-violet rays, 8, 11
"Upward" system of ventilation, 62, 74
United States Children's Bureau, report of house ventilation and children's health, 26

Vasomotor tone, decreased by rise in temperature, 14
Variability, importance of, 5, 6
Ventilation, beginning of study, 33
defined, 32
"compulsory," 48, 49
effect on children in homes, 26
mechanical, 48
not automatic, 105
of banks, 135

Ventilation (continued)
of basements, 135
of bedrooms, 141
of churches, 137
of factories, 113-128
of offices, 130-132
of homes, 138
of inside rooms, 116
of mezzanine floors, 134, 135
of stores, 133
practice, 63
problem in industry, 27
pupil participation in, 104-105
standard for, 34
"standard" practice, 54
supervision of, 51, 102, 103, 117
waste in, 150
Vernon, H. M., factory output increased by good ventilation, 120
use of hot-wire anemometer, 122, 123, 174, 175
"Vitaglass," for ultra-violet rays, 11
Vosmaer, A., use of ozone, 58, 59

"Washed air," 58
Watt, William E., comparison of Watt and Wheeler systems, 93, 94
crusades for fresh air, 87
Watt, influenced by open-air school, 85, 86
opens windows at top, 91
two-way duct, 113
work in Rochester, 114, 137
Wheeler, Samuel H., system of ventilation, 90-94, 107, 138, 139, 147
Wilson, D. R., 121
Window-gravity, ventilation, at Coleman school, Gardner, Mass., 109
cost to install, 145, 146, 150
endorsed for schools, 51, 52, 62
exhibits, 184, 185
gaining headway, 106
in banks, 135, 136
in churches, 137
in factories, 113, 128
in homes, 138, 139
in office buildings, 130-132
in stores, 133
in theaters, 136
lessens odors, 115, 116
opinions of school superintendents about, 106-108
saves fuel, 120, 147
simplicity of, 139
schools using it, 106
two systems contrasted, 93, 94, 96

Windows, 51
double-hung, vertically sliding best, 132
types compared, 152
how to open, 153, 155

Wind tunnel, description of, 15
Winslow, C.-E. A., difference between high outdoor summer and high indoor winter temperatures, 28
Winslow, inconsistencies in law, 73
pamphlet for janitors, 102
purpose of study of N. Y. State Commission on Ventilation, 73
value of thermostat, 170
ventilation laws meaningless, 71
Wisconsin, ventilation code, 69, 81, 82
Wolpert, 7
Wood, Mrs. Ira Couch, 87

ON MAINTAINING GOOD HEALTH

BLOOD PRESSURE

By Lewellys F. Barker, M.D., and Norman B. Cole, M.D. Dispels misconceptions, gives sound advice, and tells what a layman wants to know on a subject of increasing interest. $1.25

YOUR HEART AND HOW TO TAKE CARE OF IT

By Robert H. Babcock, M.D. Banishes needless worry and indicates the proper precautions and habits of living to guard against ailments of the heart. $1.50

GOOD HEALTH

By Alvah H. Doty, M.D. Tells the person not in good health how to get it, and tells anyone how to maintain good health once it is established. $2.00

WALKING FOR HEALTH

By Alvah H. Doty, M.D. Explains the advantages of the best and most available way to keep in trim. 50c

WALTER CAMP'S HANDBOOK OF HEALTH AND HOW TO KEEP IT

By Walter Camp. A sane, universally available system whereby anyone may keep himself normally fit. $1.25

COLDS

By Russell L. Cecil, M.D. A simple explanation of the cause, treatment and prevention of the common cold. $1.00

D. APPLETON AND COMPANY

New York **London**

BOOKS ON HEALTH AND HYGIENE

THE HOME MEDICAL ADVISER

By Kenelm Winslow, M.D. A complete, up-to-date and helpful book that is invaluable in the home. Information on all diseases that occur under home conditions and their remedies, in simple language. Illustrated. $5.00

HOW TO REDUCE—New Waistlines for Old

By Antoinette Donnelly. An expert writes in pithy paragraphs of how to secure slimness without making a martyr of oneself. Illustrated. $1.00

CARE OF THE SKIN AND HAIR

By William A. Pusey, M.D. A popular discussion, by a specialist, on hair and skin hygiene, with simple methods for keeping both healthy and ornamental. $1.50

CARE OF THE TEETH

By S. A. Hopkins, M.D., D.D.S. This practical guide to the care of the teeth is written with a view to the actual needs of the family. $1.25

RACE HYGIENE AND HEREDITY

By Herman W. Siemens. Translated and Edited by Lewellys F. Barker. The facts of heredity as now understood, and their bearing on human welfare. $2.00

BYWAYS TO HEALTH—
Or Detouring the Scrap-Heap

By Thomas D. Wood, M.D. and Theresa Dansdill. Lays down the rules of health in sane, informal, practical style. $1.50

D. APPLETON AND COMPANY

New York London

BETTER HEALTH INCORPORATED
MEDICO-DENTAL BLDG. 490 POST STREET
SAN FRANCISCO, CAL.

LANE MEDICAL LIBRARY

This book should be returned on or before
the date last stamped below.

I770 Wood, T.D. 98641
W87 Ventilation and
1927 health.

NAME	DATE DUE